

AD-A083 943

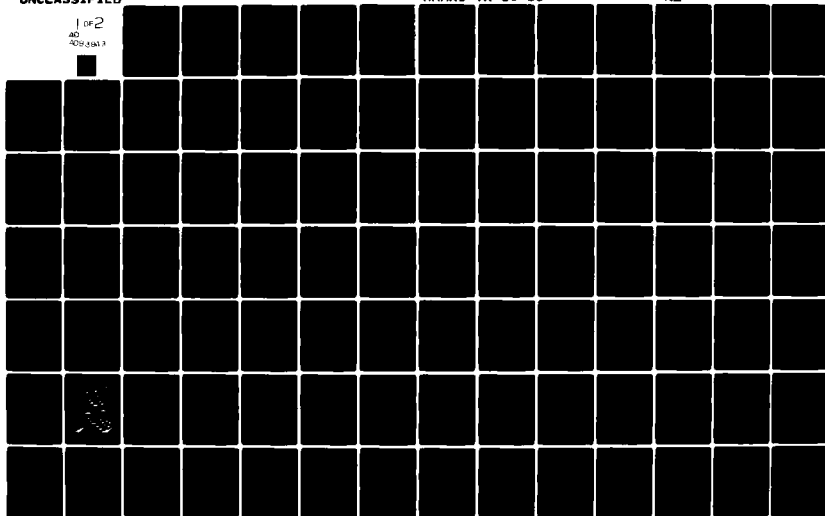
CENTER FOR INFORMATION AND NUMERICAL DATA ANALYSIS AN--ETC F/G 5/2  
THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS C--ETC(U)  
MAR 80 C HO DLA900-79-C-1007

UNCLASSIFIED

AMMRC-TR-80-15

NL

1 OF 2  
AD  
A083 943



ADA 083943



LEVEL 4

(2)

AD

AMMRC TR 80-15

**THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION  
ANALYSIS CENTER (TEPIAC)**

**A Continuing Systematic Program on Data Tables of Thermophysical  
and Electronic Properties of Materials**

**March 1980**

**Center for Information and Numerical Data Analysis and Synthesis  
Purdue University  
West Lafayette, Indiana 47906**

**Annual Final Report - Contract DLA900-79-C-1007**

Approved for public release; distribution unlimited.

**DTIC  
ELECTE  
MAY 5 1980  
S D  
A**

Prepared for

**ARMY MATERIALS AND MECHANICS RESEARCH CENTER  
Watertown, Massachusetts 02172**

DDC FILE COPY

80 5 5 134

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER AMMRC/TR-80-15	2. GOVT ACCESSION NO. AD-A083943 (9)	3. RECIPIENT'S CATALOG NUMBER (Final)	
4. TITLE (and Subtitle) THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC): A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials,		5. TYPE OF REPORT & PERIOD COVERED Annual Final Report, 1 Jan 1979 to 31 Dec 1979	
7. AUTHOR(s) Cho-Yen/Ho	8. CONTRACT OR GRANT NUMBER(s) DLA900-79-C-1007		
9. PERFORMING ORGANIZATION NAME AND ADDRESS Center for Information and Numerical Data Analysis and Synthesis, Purdue University, 2595 Yeager Rd., West Lafayette, Indiana 47906		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS D/A Project: AMCMS Code: Agency Accession:	
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Logistics Agency, ATTN: DLA-SCT Cameron Station Alexandria, VA 22314		12. REPORT DATE Mar 1980	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Army Materials and Mechanics Research Center ATTN: DRXMR-P Arsenal Street Watertown, MA 02172		13. NUMBER OF PAGES 111	
		15. SECURITY CLASS. (of this report) Unclassified	
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited.			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Thermophysical properties, thermodynamic properties, transport properties, electronic properties, electrical properties, magnetic properties, optical properties, metals, alloys, ceramics, cermets, intermetallics, polymers, composites, elements, compounds, glasses, coatings, systems, materials, data compilation, data evaluation, data analysis, Information Analysis Center.			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This Annual Final Report on Contract No. DLA900-79-C-1007 covers the activities and accomplishments of the Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) for the period 1 January to 31 December 1979. TEPIAC's activities reported herein include literature search, acquisition, and input of source information; documentation review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction			

DD FORM 1473

1 JAN 73

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

+01113

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

## 20. ABSTRACT (continued)

and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. TEPIAC is one of the most efficient and cost-effective Full-Service Information Analysis Centers when evaluated on input and output volumes per budgeted dollar. During this 12-month reporting period, TEPIAC screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 research documents while completely overhauled the computerized bibliographic information system, extracted and compiled 2,675 sets of property data from 842 data source documents by processing 2,148 research documents in addition to performing data evaluation, correlation, analysis, and synthesis and generating recommended reference values, and responded to 562 inquiries from government laboratories and agencies, defense contractors and other industrial organizations, and academic institutions. Furthermore, under multiple sponsorship four volumes of data books of the new CINDAS Data Series on Material Properties with a total of 1,553 pages and another data book with 280 pages were completed. Two state-of-the-art reports with a total of 396 pages were completed and released, three state-of-the-art reports completed previously were published in the Journal of Physical and Chemical Reference Data, ten volumes of research literature retrieval guides and supplements with a total of 3,077 pages were published, six issues of the "Thermophysics and Electronics Newsletter" with a total of 66,000 copies and three promotional brochures with a total of 9,000 copies were distributed. TEPIAC sponsored two international conferences and TEPIAC staff participated in fourteen other conferences and meetings. A promotional and documentary film entitled "The Anatomy of Data" produced previously has been shown to about 184 organizations.

Approved on For	
1. 10/1/76	<input checked="" type="checkbox"/>
2. 10/1/76	<input type="checkbox"/>
3. 10/1/76	<input type="checkbox"/>
4. 10/1/76	<input type="checkbox"/>
5. 10/1/76	<input type="checkbox"/>
6. 10/1/76	<input type="checkbox"/>
7. 10/1/76	<input type="checkbox"/>
8. 10/1/76	<input type="checkbox"/>
9. 10/1/76	<input type="checkbox"/>
10. 10/1/76	<input type="checkbox"/>
11. 10/1/76	<input type="checkbox"/>
12. 10/1/76	<input type="checkbox"/>
13. 10/1/76	<input type="checkbox"/>
14. 10/1/76	<input type="checkbox"/>
15. 10/1/76	<input type="checkbox"/>
16. 10/1/76	<input type="checkbox"/>
17. 10/1/76	<input type="checkbox"/>
18. 10/1/76	<input type="checkbox"/>
19. 10/1/76	<input type="checkbox"/>
20. 10/1/76	<input type="checkbox"/>
21. 10/1/76	<input type="checkbox"/>
22. 10/1/76	<input type="checkbox"/>
23. 10/1/76	<input type="checkbox"/>
24. 10/1/76	<input type="checkbox"/>
25. 10/1/76	<input type="checkbox"/>
26. 10/1/76	<input type="checkbox"/>
27. 10/1/76	<input type="checkbox"/>
28. 10/1/76	<input type="checkbox"/>
29. 10/1/76	<input type="checkbox"/>
30. 10/1/76	<input type="checkbox"/>
31. 10/1/76	<input type="checkbox"/>
32. 10/1/76	<input type="checkbox"/>
33. 10/1/76	<input type="checkbox"/>
34. 10/1/76	<input type="checkbox"/>
35. 10/1/76	<input type="checkbox"/>
36. 10/1/76	<input type="checkbox"/>
37. 10/1/76	<input type="checkbox"/>
38. 10/1/76	<input type="checkbox"/>
39. 10/1/76	<input type="checkbox"/>
40. 10/1/76	<input type="checkbox"/>
41. 10/1/76	<input type="checkbox"/>
42. 10/1/76	<input type="checkbox"/>
43. 10/1/76	<input type="checkbox"/>
44. 10/1/76	<input type="checkbox"/>
45. 10/1/76	<input type="checkbox"/>
46. 10/1/76	<input type="checkbox"/>
47. 10/1/76	<input type="checkbox"/>
48. 10/1/76	<input type="checkbox"/>
49. 10/1/76	<input type="checkbox"/>
50. 10/1/76	<input type="checkbox"/>
51. 10/1/76	<input type="checkbox"/>
52. 10/1/76	<input type="checkbox"/>
53. 10/1/76	<input type="checkbox"/>
54. 10/1/76	<input type="checkbox"/>
55. 10/1/76	<input type="checkbox"/>
56. 10/1/76	<input type="checkbox"/>
57. 10/1/76	<input type="checkbox"/>
58. 10/1/76	<input type="checkbox"/>
59. 10/1/76	<input type="checkbox"/>
60. 10/1/76	<input type="checkbox"/>
61. 10/1/76	<input type="checkbox"/>
62. 10/1/76	<input type="checkbox"/>
63. 10/1/76	<input type="checkbox"/>
64. 10/1/76	<input type="checkbox"/>
65. 10/1/76	<input type="checkbox"/>
66. 10/1/76	<input type="checkbox"/>
67. 10/1/76	<input type="checkbox"/>
68. 10/1/76	<input type="checkbox"/>
69. 10/1/76	<input type="checkbox"/>
70. 10/1/76	<input type="checkbox"/>
71. 10/1/76	<input type="checkbox"/>
72. 10/1/76	<input type="checkbox"/>
73. 10/1/76	<input type="checkbox"/>
74. 10/1/76	<input type="checkbox"/>
75. 10/1/76	<input type="checkbox"/>
76. 10/1/76	<input type="checkbox"/>
77. 10/1/76	<input type="checkbox"/>
78. 10/1/76	<input type="checkbox"/>
79. 10/1/76	<input type="checkbox"/>
80. 10/1/76	<input type="checkbox"/>
81. 10/1/76	<input type="checkbox"/>
82. 10/1/76	<input type="checkbox"/>
83. 10/1/76	<input type="checkbox"/>
84. 10/1/76	<input type="checkbox"/>
85. 10/1/76	<input type="checkbox"/>
86. 10/1/76	<input type="checkbox"/>
87. 10/1/76	<input type="checkbox"/>
88. 10/1/76	<input type="checkbox"/>
89. 10/1/76	<input type="checkbox"/>
90. 10/1/76	<input type="checkbox"/>
91. 10/1/76	<input type="checkbox"/>
92. 10/1/76	<input type="checkbox"/>
93. 10/1/76	<input type="checkbox"/>
94. 10/1/76	<input type="checkbox"/>
95. 10/1/76	<input type="checkbox"/>
96. 10/1/76	<input type="checkbox"/>
97. 10/1/76	<input type="checkbox"/>
98. 10/1/76	<input type="checkbox"/>
99. 10/1/76	<input type="checkbox"/>
100. 10/1/76	<input type="checkbox"/>

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

## SUMMARY

The Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) is a Full-Service Department of Defense Information Analysis Center operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University under contract with the Defense Logistics Agency (DLA) and under the technical direction of the Army Materials and Mechanics Research Center (AMMRC). The objective of TEPIAC operations is to increase the productivity of scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense by maintaining a comprehensive, authoritative, and up-to-date national data base on thermophysical and electronic (including also electrical, magnetic, and optical) properties of materials for use by the entire DOD community and by providing authoritative data and information analysis services. Its major functions are to search, collect, review, evaluate, appraise, analyze, synthesize, and summarize the available scientific and technical data and information from worldwide sources on the various thermophysical, electronic, electrical, magnetic, and optical properties of materials and to disseminate the results both by providing authoritative data and information directly to the individual users through technical and bibliographic inquiry services and by publishing major reference works on property data and information for the general users at large.

TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments.

This Annual Final Report on Contract No. DLA900-79-C-1007 covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported herein include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts.

TEPIAC is one of the most efficient and cost-effective Full-Service Information Analysis Centers when evaluated on input and output volumes per budgeted dollar. During this 12-month reporting period, the Center screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 research documents while completely overhauled the computerized bibliographic information system, extracted and compiled 2,675 sets of property data from 842 data source documents by processing 2,148 research documents in addition to performing data evaluation, correlation, analysis, and synthesis and generating recommended reference values, and responded to 562 inquiries from government laboratories and agencies, defense contractors and other industrial organizations, and academic institutions. Furthermore, under multiple sponsorship four volumes of data books of the new CINDAS Data Series on Material Properties with a total of 1,553 pages and another data book with 280 pages were completed. Two state-of-the-art reports with a total of 396 pages were completed and released, three state-of-the-art reports completed previously were published in the Journal of Physical and Chemical Reference Data, ten volumes of research literature retrieval guides and supplements with a total of 3,097 pages were published, six issues of the "Thermophysics and Electronics Newsletter" with a total of 66,000 copies and three promotional brochures with a total of 9,000 copies were distributed. TEPIAC sponsored two international conferences and TEPIAC staff participated in fourteen other conferences and meetings. A promotional and documentary film entitled "The Anatomy of Data" produced previously has been shown to about 184 organizations. A statistical summary of TEPIAC accomplishments is presented in Table 1.

TABLE 1. STATISTICAL SUMMARY OF TEPIAC ACCOMPLISHMENTS

(For the Period 1 January to 31 December 1979)

	This Period	Total as of 31 December 1979
<u>Scope</u>		
Properties covered . . . . .	36	36
Materials covered . . . . .	39,741	39,741
<u>Scientific Documentation</u>		
Abstracts screened . . . . .	750,000	43,960,000
Relevant abstracts scrutinized . . . . .	46,000	758,300
Pertinent documents identified . . . . .	11,400	222,200
Documents on hand . . . . .	17,634	183,331
Documents reviewed, coded, and catalogued . . . . .	1,837	153,382
Entries of codification . . . . .	a	557,085 <sup>a</sup>
Sources of documents . . . . .	8,630	8,630
<u>Data Table Generation</u>		
Documents processed . . . . .	2,148	44,855
Data source documents resulted . . . . .	842	20,496
Data sets compiled . . . . .	2,675	93,713
Data sets in the Evaluated Numerical Data Bank . . . . .	---	4,268
<u>Inquiry Services</u>		
Inquiries from government laboratories and agencies . . . . .	69	1,091 <sup>b</sup>
Inquiries from defense contractors and other industrial organizations . . . . .	357	4,007 <sup>b</sup>
Inquiries from academic institutions . . . . .	136	2,046 <sup>b</sup>
Total inquiries . . . . .	562	7,144 <sup>b</sup>
<u>Publications</u>		
Research Literature Retrieval Guides and Supplements		
Number of volumes . . . . .	10	19
Number of pages . . . . .	3,097	8,258
Data Books and Handbooks		
Number of volumes . . . . .	5	29
Number of pages . . . . .	1,833	30,514
State-of-the-art reports and technical reports		
Number of reports . . . . .	2	31
Number of pages . . . . .	396	5,012
Masters Theses in the Pure and Applied Sciences		
Number of volumes . . . . .	1	23
Number of pages . . . . .	292	5,153
<u>Current Awareness and Promotion Efforts</u>		
Thermophysics and Electronics Newsletter		
Number of issues . . . . .	6	48
Number of copies . . . . .	66,000	260,100
Promotional brochures		
Number of brochures . . . . .	3	19
Number of copies . . . . .	9,000	51,650
Conferences and meetings		
Number of conferences and meetings sponsored . . . . .	2	16
Number of conferences and meetings participated . . . . .	14	145
Documentary film . . . . .	---	1

<sup>a</sup> See footnotes b and c to Table 2 on page 9.<sup>b</sup> Since 1963.

## PREFACE

This Annual Final Report was prepared by the Thermophysical and Electronic Properties Information Analysis Center (TEPIAC), a Department of Defence Information Analysis Center (IAC). This Center is operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS), Purdue University, West Lafayette, Indiana, under Contract No. DLA900-79-C-1007 with the Defense Logistics Agency (DLA), Alexandria, Virginia, with Mr. J. L. Blue being the IAC Program Manager, and under the technical direction of the Army Materials and Mechanics Research Center (AMMRC), Watertown, Massachusetts, with Mr. Samuel Valencia being the Contracting Officer's Technical Representative. The Contract was issued by the Defense Electronics Supply Center, Dayton, Ohio, with Mr. S.C. Rosta and Mrs. Frances Burke being the Contracting Officers.

The present Contract is for a period of three years from 1 January 1979 to 31 December 1981. This Annual Final Report covers only the first year from 1 January to 31 December 1979, and was submitted to fulfill the contractual requirement (Item No. 0002, Sequence No. A002).

The work reported herein is credited to the collective efforts of the entire staff of the Thermophysical and Electronic Properties Information Analysis Center. Dr. Y. S. Touloukian, Director of CINDAS, and Dr. C. Y. Ho, Assistant Director-Research, have been the principal investigators.

This report has been reviewed and is approved.



# TABLE OF CONTENTS

	<u>Page</u>
SUMMARY . . . . .	iii
PREFACE . . . . .	vi
I. INTRODUCTION . . . . .	1
II. SCIENTIFIC DOCUMENTATION ACTIVITIES . . . . .	6
1. Literature Search, Acquisition, and Input of Source Information . . . . .	6
2. Document Review and Codification, Material Classification, and Information Organization . . . . .	11
3. Computerized Bibliographic Information Storage and Retrieval System . . . . .	14
4. Research Literature Retrieval Guides and Supplements . . . . .	17
III. DATA TABLES ACTIVITIES . . . . .	23
1. Data Extraction and Compilation . . . . .	23
2. Data Evaluation, Correlation, Analysis, Synthesis, and Generation of Recommended Values . . . . .	25
3. Handbooks and Data Books . . . . .	41
4. State-of-the-Art Reports, Critical Reviews, and Technology Assessments . . . . .	52
5. Carbon-Carbon Composites Data Bank . . . . .	53
6. Computerized Numerical Data Storage and Retrieval System . . . . .	54
IV. INQUIRY SERVICES . . . . .	56
V. CURRENT AWARENESS AND PROMOTION EFFORTS . . . . .	64
VI. OTHER PUBLICATIONS NOT UNDER THIS CONTRACT BUT IN DIRECT SUPPORT OF THIS PROGRAM . . . . .	67
VII. CONCLUSIONS AND FUTURE PLANNING . . . . .	70
APPENDICES . . . . .	73
1. Table of Contents of the Four-Completed Volumes of the "McGraw-Hill/CINDAS Data Series on Material Properties" . . . . .	74
Volume II-1. Thermal Accommodation and Adsorption Coefficients of Gases . . . . .	74
Volume II-2. Physical Properties of Rocks and Minerals . . . . .	77
Volume III-1. Properties of Selected Ferrous Alloying Elements . . . . .	85
Volume III-2. Properties of Nonmetallic Fluid Elements . . . . .	88

2.	Table of Contents of the Completed Data Book Entitled "Viscosity of Dense Fluids" . . . . .	91
3.	TEPIAC Technical Inquiry Questionnaire . . . . .	92
4.	Survey Results from TEPIAC Technical Inquiry Questionnaire . .	93
5.	Organizations Using TEPIAC Inquiry Services . . . . .	96

# LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Statistical Summary of TEPIAC Accomplishments . . . . .	v
2	Statistical Summary of Scientific Documentation Accomplishments . . . . .	9
3	Code Designation for Codification of Literature . . . . .	13
4	Thermophysical Properties File Composition . . . . .	15
5	Electronic Properties File Composition . . . . .	16
6	Statistical Data on Thermophysical Properties Coverage of the World Literature . . . . .	19
7	Statistical Data on Electronic Properties Coverage of the World Literature . . . . .	20
8	Thermophysical Properties Research Literature Retrieval Guide, Supplement II . . . . .	22
9	Electronic Properties Research Literature Retrieval Guide, Basic CINDAS Edition . . . . .	22
10	Statistical Summary of Accomplishments of Data Extraction and Compilation . . . . .	24
11	Summary of Statistical Data on "Thermophysical Properties of Matter - The TPRC Data Series" . . . . .	45
12	Structure and Scope of "McGraw-Hill/CINDAS Data Series on Material Properties" . . . . .	47
13	Properties Covered by "McGraw-Hill/CINDAS Data Series on Material Properties" . . . . .	49
14	Statistical Summary of Inquiry Responses for 1979 . . . . .	57
15	Geographical Distribution of Inquiry Responses for 1979 . . . . .	58
16	Interest Profile of Technical Inquiries . . . . .	63
17	Conferences and Meetings Participated in by TEPIAC Staff Members in the Period 1 January to 31 December 1979 . . . . .	65
18	Statistical Summary of Coverage of "Masters Theses in the Pure and Applied Sciences" . . . . .	68
19	Academic Disciplines Covered by the "Masters Theses in the Pure and Applied Sciences" . . . . .	69

# LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Technical Coding Form . . . . .	12
2	Experimental Data and Recommended Values on the Thermal Conductivity of Titanium Carbide . . . . .	28
3	Experimental Data and Recommended Values on the Thermal Conductivity of Platinum (60%) + Rhodium (40%) Alloy . . . . .	29
4	Experimental Data and Recommended Values on the Thermal Conductivity of Tungsten . . . . .	30
5	Experimental Data and Recommended Values on the Thermal Diffusivity of Tungsten . . . . .	31
6	Experimental Data on the Thermal Conductivity of Aluminum + Copper Alloys . . . . .	33
7	Recommended Values for the Thermal Conductivity of Aluminum + Copper Alloys . . . . .	34
8	Experimental Data on the Absolute Thermoelectric Power of Nickel + Copper Alloys . . . . .	35
9	Recommended Values for the Absolute Thermoelectric Power of Nickel + Copper Alloys . . . . .	36
10	Experimental Data and Recommended and Provisional Values on the Refractive Index of Lithium Chloride . . . . .	37
11	Recommended and Provisional Values for the Refractive Index of All Twenty Alkali Halides . . . . .	38
12	Recommended and Provisional Values for the Temperature Derivative of the Refractive Index of All Twenty Alkali Halides . . . . .	39
13	Provisional Values for the Wavelength Derivative of the Refractive Index of All Twenty Alkali Halides . . . . .	40
14	Experimental Data on the Refractive Index of Silicon (Wavelength Dependence) . . . . .	42
15	Experimental Data on the Refractive Index of Silicon (Temperature Dependence). . . . .	43
16	Recommended Values for the Refractive Index of Silicon as a Function of Both Wavelength and Temperature Simultaneously . . . . .	44
17	Summary of Inquiry Responses Since 1963 . . . . .	59

## SECTION I

### INTRODUCTION

The Thermophysical and Electronic Properties Information Analysis Center (TEPIAC) is a Department of Defense Information Analysis Center operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University. Under CINDAS' operation, TEPIAC has long achieved the full operational status of a Full-Service DOD Information Analysis Center, and TEPIAC has been well oriented to the needs of its user community with its products and services well-known.

The objective of TEPIAC operations is to increase the productivity of scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense by maintaining a comprehensive, authoritative, and up-to-date national data base on thermophysical and electronic (including also electrical, magnetic, and optical) properties of materials for use by the entire DOD community and by providing authoritative data and information analysis services. Services are also rendered to other U.S. Government Agencies and their contractors and, to the extent practical without impairment of services to the foregoing users, to the private sector, consistent with security and other limitations on TEPIAC's information.

The major functions of TEPIAC are to search, collect, review, evaluate, appraise, analyze, synthesize, and summarize the available scientific and technical data and information from worldwide sources on the various thermophysical, electronic, electrical, magnetic, and optical properties of materials and furthermore to disseminate the results both by providing authoritative data and information directly to the individual TEPIAC users through technical and bibliographic inquiry services and by publishing major reference works on property data and information for the general TEPIAC users at large.

TEPIAC's major tasks and activities include literature search, acquisition, and input of source information for maintaining the data base; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks,

data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; technical and bibliographic inquiry services; and current awareness and promotion efforts.

While TEPIAC is a full-service IAC, it has traditionally stressed data evaluation and analysis and the generation of reference data more than any other single group anywhere. Furthermore, it has always felt that the maximum optimization of its efforts in serving the end users of data and information can best be realized through the publication of major reference works, whereby the data and information are readily available at arm's reach of the engineers, scientists, and technicians. Towards this end, TEPIAC has contributed greatly over the years by publishing a number of the most comprehensive and authoritative series of data books and handbooks published anywhere.

It is appropriate at this point to discuss briefly the importance of the knowledge of thermophysical, electronic, electrical, magnetic, and optical properties of materials covered by TEPIAC to the mission of the Department of Defense and the important role of Information Analysis Centers such as TEPIAC in national defense. There is no doubt that the knowledge of material properties is extremely important to the mission of the Department of Defense because the proper design of defense systems and military weapons, hardware, equipment, structures, etc. used in national defense requires a complete knowledge of the properties of materials. Consider first an example that concretely demonstrates the importance and usefulness of such knowledge to the Department of Defense and, as a consequence, that the mission of the Department of Defense is accomplished in a most competent manner with such knowledge. It is well known that a thorough knowledge of thermal conductive and radiative properties of refractory, insulation, and other aerospace materials is a fundamental requirement of the design of advanced weapons such as ballistic missiles and spacecraft which require thermal protection systems for their operating at extremes in temperature and require lightweight high-efficiency thermal insulation systems for cryogenic fuel in booster applications. The thermal conductive and radiative properties of refractory and composite materials used in nose cones, nozzles, and leading edges are so important that these properties determine directly the temperature level of operation, and furthermore, together with thermal expansion they determine the thermal stress and thermal shock characteristics, which are most important design considerations for high temperature applications. In short,

without the knowledge of these properties, the design of spacecraft, ballistic missiles, and all other similar warhead delivery systems would not have been possible, and this Nation's advanced defense systems and space programs could not be off the ground.

For the design of conventional military vehicles, tanks, airplanes, and warships or their power-plants and of various firearms ranging from small guns to heavy artilleries, the knowledge of thermal conductive, radiative, and other thermophysical properties is also very essential because their operations always involve rapid heat generation and high thermal stress and thus require efficient heat dissipation or cooling; all such processes are directly related to thermophysical properties of the materials used. Thermophysical properties of fluids are important in the design of engine cooling system, lubricating system, fuel system, combustion and exhaust system, etc. For the design of nuclear engine used in a submarine or warship, the knowledge of the thermophysical properties of nuclear fuel materials and fuel rod cladding materials is essential since these properties determine the maximum attainable heat flux from fuel rods and the temperature level of operation, which dictate almost the entire design.

In the current advanced technology, the knowledge of thermal radiative properties as well as optical properties is most essential both in the development of high-power laser weaponry for destroying enemy's aircrafts, missiles, satellites, etc. and in the development of laser-hardened materials for protecting our aircrafts, missiles, satellites, etc. against enemy's high-power laser attack. The knowledge of thermal radiative and optical properties is also extremely important in the development of target signature recognition systems for detecting and identifying enemy's oncoming aircrafts and missiles and for identifying terrestrial objects in guidance and reconnaissance applications.

The knowledge of electronic, electrical, and magnetic properties of materials is, of course, essential for the design of all electronic devices and equipment for military applications, including, for example, those electronic devices used in military electronic communication, electronic high-speed computation, electronic guidance, control, and tracking, electronic detection and sensing, electromagnetic memory and recording, electronic surveillance, reconnaissance, and intelligence, electronic jamming, deception, and countermeasure, and those military electronic devices for energy generation, storage, conversion, and

transmission. In fact, the rapid advance in electronic gadgetry in recent years is a direct result of increased knowledge of the electronic, electrical, and magnetic properties of materials, unusual or otherwise. In electronic devices, the availability of efficient heat sinks for micro-circuits is another essential requirement for their satisfactory performance, and the design of efficient heat sinks requires the knowledge of thermophysical properties. It is indeed an endless list of examples demonstrating the great importance and usefulness to the Department of Defense of the knowledge of thermophysical, electronic, electrical, magnetic, and optical properties, of which TEPIAC is responsible for coverage.

In the past, the data and information on the properties of materials, though so important, were buried in the world's enormous and ever-expanding volume of scientific and technical literature, and the scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense used no more than a small fraction of the data and information already existing. This disturbing situation has been gradually improved since the establishment of the scientific and technical Information Analysis Centers, such as TEPIAC, by the Department of Defense. TEPIAC has been conducting a continuing systematic program to dig the buried data and information and to screen and filter the current data and information out of the world's ever-increasing volume of literature and to critically evaluate, appraise, analyze, synthesize, summarize, and put the data and information in a form most useful to the users in the entire Defense community. There is no doubt that the more accurately the properties of materials are known, the more likely that a system can be designed properly and performed successfully, and that the more readily the property data and information are available, the more likely that a development program can be expedited.

The important role of TEPIAC, or of any other DOD Information Analysis Center, in national defense is to assure that the Department of Defense carries out its mission timely and most effectively by serving as a focal point for authoritative expertise and maintaining a national data base within the scope of its coverage to be tapped by the Department of Defense and its contractors for solutions to technological problems and for the planning of advanced defense systems, by providing instant response to meet urgent requirements of the Department of Defense when short reaction time is essential, by serving as a



vehicle for effective technology transfer within its scope, thus closing the time gap between R&D and application, by having complete cognizance of the topography of the state of knowledge within its scope, thus able to quickly identify areas where knowledge is lacking and research is required to meet existing needs and anticipated future demands, and by bringing about significant cost savings to the Department of Defense and others by preventing the use of erroneous input data in critical technical applications and avoiding duplication in present and future research efforts. In short, TEPIAC and other DOD Information Analysis Centers play a very significant role in our national defense.

CINDAS, who operates TEPIAC, is a part of Purdue University, which is one of the leading institutions of higher learning in the Nation. Purdue University has numerous research laboratories in all fields and disciplines and many of these are for the measurement and research on thermophysical and/or electronic properties. Furthermore, there are over 2500 highly-trained faculty members and research specialists at Purdue. When the need arises CINDAS/TEPIAC can draw on their scientific and engineering expertise with immediate access.

Due to the fact that CINDAS' own staff, with its 13 doctoral level professional personnel, possess a very high degree of expertise in thermophysical and electronic properties, material science, solid state physics, physical chemistry, and spectroscopy, the assistance from outside CINDAS is, therefore, seldom needed. CINDAS/TEPIAC' staff have an enviable performance record of scientific and professional accomplishments through original research contributions to the primary literature. Thus they possess a high level of professional recognition and credibility in their work, which is absolutely essential for acceptance by their peers. Some of the staff have received honors and distinctions from National and International scientific and technical bodies. In the area of scientific documentation its staff comprise highly trained personnel (several staff having a degree of Master of Science) with an average of over 12 years experience in their speciality. On its premises CINDAS has an experimental research laboratory for the measurements of thermophysical and electronic properties which is recognized as a most outstanding laboratory with a wide range of "state-of-the-art" capabilities. The work of this laboratory contributes directly to the data evaluation and analysis process, which constitutes a unique and invaluable asset to TEPIAC.

TEPIAC's accomplishments in all its tasks and activities in the performance of this contract for the 12-month period from 1 January 1979 to 31 December 1979 are detailed in the following sections.

## SECTION II

### SCIENTIFIC DOCUMENTATION ACTIVITIES

In order to maintain a comprehensive, authoritative, and up-to-date national data base on thermophysical, electronic, electrical, magnetic, and optical properties of materials and to provide authoritative information and data to the users with instant retrieval capability, TEPIAC has maintained a systematic program of literature search and acquisition, document review and codification, material classification, information organization, and of storing the resulting information in a computerized information storage and retrieval system. The various phases of activities in this program are discussed below.

#### 1. LITERATURE SEARCH, ACQUISITION, AND INPUT OF SOURCE INFORMATION

The fourteen thermophysical properties under TEPIAC cognizance of information and data in all pertinent subject areas are as follows:

1. Thermal conductivity
2. Accommodation coefficient
3. Thermal contact resistance
4. Thermal diffusivity
5. Specific heat at constant pressure
6. Viscosity
7. Emittance
8. Reflectance
9. Absorptance
10. Transmittance
11. Solar absorptance to emittance ratio
12. Prandtl number
13. Thermal linear expansion coefficient
14. Thermal volumetric expansion coefficient

Originally two more properties (diffusion coefficient and surface tension) had been monitored, but these were dropped in mid-1970.

The fifteen specific electronic, electrical, magnetic, and optical properties and seven property groups under TEPIAC cognizance of information and data in all pertinent subject areas are as follows:

### Properties

- |                           |                             |
|---------------------------|-----------------------------|
| 1. Absorption coefficient | 9. Energy levels            |
| 2. Dielectric constant    | 10. Hall coefficient        |
| 3. Dielectric strength    | 11. Magnetic hysteresis     |
| 4. Effective mass         | 12. Magnetic susceptibility |
| 5. Electric hysteresis    | 13. Mobility                |
| 6. Electrical resistivity | 14. Refractive index        |
| 7. Energy bands           | 15. Work function           |
| 8. Energy gap             |                             |

### Property Groups

- |                                  |                                  |
|----------------------------------|----------------------------------|
| 16. Electron emission properties | 19. Magnetomechanical properties |
| a. Field emission                | a. Anisotropy energy             |
| b. Photoemission                 | b. Magnetostriction              |
| c. Secondary emission            | 20. Photoelectronic properties   |
| d. Thermionic emission           | a. Demer effect                  |
| 17. Luminescence properties      | b. Photoconductivity             |
| a. Cathodoluminescence           | c. Photomagnetic effect          |
| b. Electroluminescence           | d. Photopiezoelectric effect     |
| c. Mechanical luminescence       | e. Photovoltaic effect           |
| d. Photoluminescence             | 21. Piezoelectric properties     |
| e. Thermoluminescence            | a. Piezoelectric effect          |
| 18. Magnetoelectric properties   | b. Pyroelectric effect           |
| a. Ettingshausen effect          | 22. Thermoelectric properties    |
| b. Magnetoresistance             | a. Peltier effect                |
| c. Nernst effect                 | b. Seebeck effect                |
| d. Shubnikov-de Haas effect      | c. Thomson effect                |

As to material coverage in this documentation phase of the program, TEPIAC covers nearly all materials at all temperatures and pressures and in all environments, which are far more than what are required by the contract. The materials required by the contract to be covered for thermophysical properties include, as a minimum, metals and metal alloys, ceramics, cermets, intermetallics, polymers, and composites, and those for electronic (including also electrical, magnetic, and optical) properties to be given priority coverage include elements, inorganic compounds, alloys, intermetallics, glasses, ceramics, cermets, applied coatings, polymers, composites, and systems.

The strategy of literature search has been to use both the abstracting journals and the scientific and technical journals. A number of selected journals have been subscribed and hundreds of the journals subscribed by Purdue Libraries have been fully utilized. The top ten high-yield scientific and technical journals for thermophysical properties are noted below:

1. Physical Review
2. Journal of Chemical Physics
3. Journal of Applied Physics
4. Russian Journal of Physical Chemistry
5. Soviet Physics - Solid State
6. Inorganic Materials (USSR)
7. Physica Status Solidi
8. Applied Optics
9. High Temperature (USSR)
10. Solid State Communications

The top ten high-yield scientific and technical journals for electronic properties are as follows:

1. Journal of Applied Physics
2. Soviet Physics - Semiconductors
3. Physica Status Solidi
4. Physical Review
5. Soviet Physics - Solid State
6. Solid State Communications
7. Physics Letters
8. Journal of Physical Society of Japan
9. AIP Conference Proceedings
10. Japanese Journal of Applied Physics

In addition to searching selected technical journals, four abstracting journals covering the open literature and four government abstracting journals covering the government report literature are monitored. These are:

1. Chemical Abstracts
2. Physics Abstracts
3. Electrical and Electronics Abstracts
4. Dissertation Abstracts International
5. Scientific and Technical Aerospace Reports (NASA)
6. Technical Abstracts Bulletin (DDC)
7. U. S. Government Reports Announcements (NTIS)
8. Technical Translations (NTIS)

In monitoring these abstracting journals, computer-screened inputs have been used. About 750,000 abstracts were screened by computer using carefully designed search logics. These basic sources and other minor sources yielded approximately 46,000 hits in this 12-month period. These 46,000 potentially good entries were further scrutinized manually to yield 4,100 pertinent references on thermophysical properties and 7,300 pertinent references on electronic properties. This and other statistical data showing TEPIAC's overall scientific documentation accomplishments in this period are presented in Table 2. Table 2 shows that 98,500 research documents on thermophysical properties and 123,700 research documents on electronic, electrical, magnetic, and optical properties

TABLE 2. STATISTICAL SUMMARY OF SCIENTIFIC DOCUMENTATION ACCOMPLISHMENTS

Thermophysical Properties

	Total as of 31 Dec. 1978	This Period	Total as of 31 Dec. 1979
Potential abstracts further scrutinized	---	18,000	---
Documents identified (references in system)	94,400	4,100	98,500
Documents on hand (microfiches and hard copies)	87,383	6,091	93,474
Documents reviewed, coded, and catalogued	76,190	868 <sup>a</sup>	77,058
Codification entries on all properties	---	---	316,516 <sup>b</sup>

Electronic Properties

	Total as of 31 Dec. 1978	This Period	Total as of 31 Dec. 1979
Potential abstracts further scrutinized	---	28,000	---
Documents identified (references in system)	116,400	7,300	123,700
Documents on hand (microfilms, microfiches, and hard copies)	78,314	11,543	89,857
Documents reviewed, coded, and catalogued	75,355	969 <sup>a</sup>	76,324
Codification entries on all properties	---	---	123,569 <sup>b,c</sup>

<sup>a</sup> Work in this area was temporarily reduced in order that the staff could overhaul and merge the two separate thermophysical properties information file and electronic properties information file into a single uniform Thermophysical and Electronic Properties Information System. In addition, efforts were expended to produce ten new retrieval guide volumes with a total of 3,097 pages.

<sup>b</sup> In the restructuring and merging of the files, some codification entries were eliminated, resulting in the net totals as shown.

<sup>c</sup> Not including the estimated 127,000 codification entries for the 49,300 documents processed before 1973 by the former EPIC. If including those, the total number of codification entries should be 240,569.

have been identified and selected for the TEPIAC data base as of 31 December 1979. It is expected that on the average about 4,000 to 4,500 research documents on thermophysical properties and 6,000 to 8,000 research documents on electronic, electrical, magnetic, and optical properties will be added to the TEPIAC data base each year.

In addition to the basic sources, TEPIAC has searched certain specialized sources such as special bibliographies, compendia, conference proceedings, symposium volumes, and listings of doctoral dissertations and master theses. Of particular note is the Kobe Affiliate<sup>a</sup> of CINDAS at Kobe, Japan, who has served a very important input function for Far Eastern literature. Furthermore, TEPIAC has continued to develop its cooperative working arrangements on the exchange of research results and information with major national and international laboratories and institutions engaged in thermophysical and/or electronic properties research. Through these highly developed procedures and arrangements, TEPIAC has a high level of confidence in regard to completeness of its input of source information.

Recent statistics shows that research documents on thermophysical and electronic properties come from the following major sources:

	<u>Percent</u>
Journal articles from Purdue library subscriptions	55.6
Journal articles from TEPIAC subscriptions	9.1
Journal articles from authors	17.5
Journal articles from Library of Congress	7.2
Government reports from DDC	5.8
Government reports from NTIS	2.9
Ph.D. dissertations and M.S. theses	0.8
Other sources	<u>1.1</u>
Total	100%

The above listing indicates that scientific and technical journal articles and other open literature constitute about 91 percent of the total research documents and government reports constitute only about 9 percent.

TEPIAC's specialized holdings of research documents, which number 93,474 on thermophysical properties and 89,857 on electronic properties as of 31 December 1979 as shown in Table 2, constitute a unique national asset and are assuming increasing importance for rapid access to the world literature on thermophysical and electronic properties. Many of these research documents, though readily available from TEPIAC, are very difficult to obtain elsewhere especially in the

<sup>a</sup> This CINDAS' overseas affiliate is supported through other sources.

cases of foreign literature and special publications of limited distribution. It is our experience that literature retrieval programs which yield only bibliographies as their end product are becoming increasingly less useful because of the difficulty and time lapse involved in procuring the cited documents. To remedy this situation, TEPIAC has long been supplementing the practice of submitting bibliographic responses to literature search requests with copies of the actual documents in the form of standard microfiche or hard copy.

## 2. DOCUMENT REVIEW AND CODIFICATION, MATERIAL CLASSIFICATION, AND INFORMATION ORGANIZATION

As each pertinent research document was received, it was immediately microfiched and then thoroughly reviewed. Pertinent information was extracted from the document with respect to the particular property measured or treated and the temperature range, the material tested and its physical state, the subject coverage of the document, and the language used. All these except the material name were translated into mnemonic code letters, and the material was assigned a material number according to an established material classification scheme. The code letters, material number, and document number were recorded on a specially designed Coding Form (see Figure 1), and were processed subsequently by computer for storage and retrieval, and also for publication of the Research Literature Retrieval Guides. The code designations for codification of literature are given in Table 3.

The number of documents reviewed and coded for retrieval was temporarily reduced because major efforts were expended to overhaul and merge the two separate thermophysical properties bibliographic information file and electronic properties bibliographic information file into a single uniform bibliographic information system hereafter referred to as the Thermophysical and Electronic Properties Information System (TEPIS). This approach is in line with our constant efforts to improve the effectiveness of our operations and should prove to be more convenient to the defense community which we serve as this merging will make it possible for scientists and engineers to access the total TEPIAC system with greater ease and in a uniform manner. Due to this diversion of efforts, only 1,837 documents on both thermophysical and electronic properties were reviewed, coded, and catalogued, as indicated in Table 2. In the restructuring and merging of the files, some codification entries were eliminated,

3 4 4 4 4 4  
8 0 1 2 3 4  
PAGE No.

# TECHNICAL CODING FORM

DATE: \_\_\_\_\_

PAGE No.

12



TABLE 3. CODE DESIGNATIONS FOR CODIFICATION OF LITERATURE

Thermophysical Properties

- A - Thermal conductivity
- B - Accommodation coefficient
- C - Thermal contact resistance
- D - Thermal diffusivity
- E - Specific heat at constant pressure
- F - Viscosity
- G - Emittance
- H - Reflectance
- I - Absorptance
- J - Transmittance
- K - Absorptance to emittance ratio
- L - Prandtl number
- N - Thermal linear expansion coefficient
- O - Thermal volumetric expansion coefficient

<u>Electronic Property</u>	<u>Dopant</u>	<u>Physical State</u>	<u>Temperature</u>
AS-Absorption coefficient	1-Group IA & IB	C-Superconductive	L-Low (0 to 75 K)
DC-Dielectric constant	2-Group IIA & IIB	D-Doped	N-Normal (above 75 K to 1273 K)
DS-Dielectric strength	3-Group IIIA	E-Expanded	or unspecified
EB-Energy band	4-Group IVA	F-Fibrous or whisker	H-High (above 1273 K)
EF-Effective mass	5-Group VA	G-Gas	F-Low + Normal + High
EG-Energy gap	6-Group VIA	I-Ionized (plasma)	
EH-Electric hysteresis	7-Group VIIA & VIIIA	L-Liquid	
EL-Energy level	8-Group IVB, VB, VIB, VIIB, & VIII	M-Multiphase	
ER-Electrical resistivity	9-Group IIIB, Lanthanide Series, Actinide Series	P-Powder or fine particle	
HC-Hall coefficient	0-Other or unspecified	S-Solid	
MH-Magnetic hysteresis		T-Thin or thick film	
MO-Mobility			
MS-Magnetic susceptibility			
RI-Refractive index			
WF-Work function			
	<u>Form of Document</u>	<u>Subject</u>	<u>Language</u>
EP-Electron emission properties	A-Coded from abstract	D-Data	C-Czechoslovakian
GP-Magnetoelectric properties	B-Coded from abstract, document available	E-Experiment	D-Dutch
LP-Luminescence properties	H-Coded from hard copy	G-Experiment + Theory + Data	E-English
MP-Magnetomechanical properties	M-Coded from microform (microfiche or microfilm)	S-Survey, review, compendium, data compilation, etc.	F-French
PP-Photoelectronic properties	T-Coded from translation	T-Theory	G-German
TP-Thermoelectric properties			I-Italian
ZP-Piezoelectric properties			J-Japanese
			O-Other
			P-Polish
			R-Russian
			S-Spanish

which resulted in a net total of 316,516 codification entries on thermophysical properties and 113,569 codification entries on electronic properties as of 31 December 1979. The latter number does not include the estimated 127,000 codification entries on electronic properties for the 49,300 documents processed before 1973 by the former EPIC. One codification entry represents usually one property of one material.

Tables 4 and 5 show the file composition for thermophysical and electronic properties, respectively, by indicating the percentages of codification entries of the various properties with respect to the total number of entries. It is noted that the percentages of codification entries for most of the properties remain fairly constant over the years.

The organization of the thermophysical and electronic properties information is by material, and thus a sound material classification scheme which can properly accommodate all materials and substances is very important. The established material classification scheme has been designed to accommodate materials and substances into similar groups, selected preferably by their chemical composition. However, because of their inherent nature, certain materials do not lend themselves to a purely chemical classification and a more logical method has been adopted to classify them, instead, by their physical form and/or use and application. The present classification scheme has been used successfully over the years for the classification of approximately 40,000 different materials and substances, for which information is available in the TEPIAC file. The end product is a most comprehensive Materials Directory, which is generated by computer.

### 3. COMPUTERIZED BIBLIOGRAPHIC INFORMATION STORAGE AND RETRIEVAL SYSTEM

The newly completed computerized Thermophysical and Electronic Properties Information System has been in full operation. By using the CDC 6500 and 6600 computer facility at Purdue University, to which TEPIAC is connected with three dedicated terminals, this new information storage and retrieval system is being used by TEPIAC to provide bibliographic searches for both thermophysical and electronic properties in response to specific inquiries. This new system has reduced operating costs, eliminated manual procedures, assured integrity of the information, and provided a more flexible, powerful, and responsive search capability.

TABLE 4. THERMOPHYSICAL PROPERTIES FILE COMPOSITION

Property	% File
Thermal conductivity	26.9
Accommodation coefficient	0.6
Thermal contact resistance	0.7
Thermal diffusivity	2.5
Specific heat at constant pressure	24.1
Viscosity	17.6
Emittance	2.9
Reflectance	5.6
Absorptance	1.2
Transmittance	3.7
Absorptance to emittance ratio	0.2
Prandtl number	0.5
Thermal linear expansion coefficient	8.3
Thermal volumetric expansion coefficient	1.0
Thermal radiative properties	4.1
	<u>100%</u>

Subject	% File	Temperature Range	% File
Data	67.5	Low (0 to 75 K)	9.1
Experiment	5.5	Normal (above 75 K to 1273 K)	62.6
Theory	15.1	High (above 1273 K)	12.0
Experiment + Theory + Data	6.8	Full range (Low + Normal + High)	0.9
Survey, review, compendium, data compilation, etc.	5.2	Unspecified	15.4
	<u>100%</u>		<u>100%</u>

Physical State	% File	Language	% File
Solid	53.3	English	71.2
Liquid	23.7	Czechoslovakian	0.1
Gas	15.7	Dutch	0.2
Doped	1.1	French	2.8
Expanded	0.4	German	7.4
Fibrous or whisker	0.3	Italian	0.6
Powder or fine particle	2.4	Japanese	1.3
Multiphase	2.9	Polish	0.1
	<u>100%</u>	Russian	15.4
		Spanish	0.2
		Others	0.8
			<u>100%</u>

TABLE 5. ELECTRONIC PROPERTIES FILE COMPOSITION

Property	% File
Absorption coefficient	7.6
Dielectric constant	4.2
Dielectric strength	0.8
Energy bands	2.1
Effective mass	1.2
Energy gap	4.9
Electric hysteresis	0.3
Energy levels	5.5
Electron emission properties	2.3
Electrical resistivity	35.2
Magnetoelectric properties	2.0
Hall coefficient	2.6
Luminescence properties	3.2
Magnetic hysteresis	2.4
Mobility	2.8
Magnetomechanical properties	0.9
Magnetic susceptibility	6.4
Photoelectronic properties	1.8
Refractive index	5.2
Thermoelectric properties	6.6
Work function	1.6
Piezoelectric properties	0.5
	100%

Subject	% File
Data	52.7
Experiment	4.2
Theory	16.0
Experiment + Theory + Data	1.0
Survey, review, compendium, data compilation, etc.	26.0
	100%

Temperature Range	% File
Low (0 to 75 K)	17.9
Normal (above 75 K to 1273 K) or unspecified	77.0
High (above 1273 K)	4.9
Full range (Low + Normal + High)	0.2
	100%

Physical State	% File
Solid	66.1
Liquid	7.3
Gas	1.1
Doped	12.2
Expanded	0.0
Fibrous or whisker	0.2
Powder or fine particle	0.3
Thin or thick film	8.9
Ionized (plasma)	0.9
Superconducting	3.0
Multiphase	0.0
	100%

Language	% File
English	77.2
Czechoslovakian	0.1
Dutch	0.0
French	1.1
German	2.8
Italian	0.1
Japanese	0.8
Polish	0.2
Russian	17.3
Spanish	0.0
Others	0.4
	100%

The new system is build around an integrated file system which provides for direct access to the desired information; this is in contrast to our previous system which performed all operations in a batch sequential mode. As a result we can more easily cross-check information in the files as well as retrieve information at a lower cost. This new system supplants the original system established some 16 years ago with many subsequent modifications.

#### 4. RESEARCH LITERATURE RETRIEVAL GUIDES AND SUPPLEMENTS

The information resulting from scientific documentation efforts on thermophysical properties is disseminated partly through the formal publication entitled "Thermophysical Properties Research Literature Retrieval Guide" and its supplements.

The Basic Edition of the Retrieval Guide which covers the publication years up to 1964 was published in 1967 and contains the resulting information from the first 33,700 research documents. Its full reference citation is as follows:

Thermophysical Properties Research Literature Retrieval Guide, Touloukian, Y.S. (Editor), Gerritsen, J.K. (Technical Editor), and Moore, N.Y. (Coordinating Editor), Basic Edition, Books 1 to 3, Plenum Press, New York, 2936 pp., 1967.

This basic edition provides a quick access to the world literature on thermophysical properties published from 1822 to June 1964. It contains 139,305 codification entries on thirteen thermophysical properties of 45,116 materials, citing 33,700 references representing 26,562 authors and 3,600 scientific and technical journals and governmental and industrial report sources.

The information on thermophysical properties resulting from the research documents with accession numbers from 33,701 up to 60,000 is contained in the Retrieval Guide Supplement I which was published in early October 1973. Its full reference citation is as follows:

Thermophysical Properties Research Literature Retrieval Guide, Supplement I (1964-1970), Touloukian, Y.S. (Editor), Gerritsen, J.K. (Technical Editor), and Shafer, W.H. (Managing Editor), Volumes 1 to 6, IFI/Plenum Data Corp., New York, 2225 pp., 1973.

This six-volume Retrieval Guide Supplement I contains 87,050 codification entries on sixteen thermophysical properties of 16,745 materials, citing 26,300 references published from mid-1964 to December 1970. An additional 9,000 synonyms and trade names are cross-referenced to assist the user in identifying the

materials of interest. Supplement I follows essentially the same format of presentation as the Basic Edition. However, it has been restructured for improved user convenience in that the six volumes are actually six independent Retrieval Guides, each of which is for a specific group of materials. As a result, each user group can purchase, at a reasonable cost, selected volumes of specific interest, as well as the complete six-volume set. Since the publication of the Retrieval Guide Supplement I in 1973, much additional information on thermophysical properties has been accumulated.

Table 6 shows the statistical data on thermophysical properties information from the world literature covered by TEPIAC, listing the number of materials in each material group, the number of codification entries for each thermophysical property, and the total numbers in our computerized bibliographic information storage and retrieval system as of 31 December 1979.

The information on electronic properties resulting from scientific documentation efforts on research documents with accession numbers up to 49,400 has been published in the "Electronic Properties of Materials: A Guide to the Literature," Volumes 1 (1681 pp., 1965), Volume 2 (1799 pp., 1967), Volume 3 (1917 pp., 1971), and Update (2980 pp., 1972). Since 1973, information on electronic properties has been accumulated from 27,024 additional research documents coded for the new computerized bibliographic information storage and retrieval system. Table 7 shows similarly the statistical data on electronic properties information from the world literature covered by TEPIAC as of 31 December 1979. The number of codification entries given in Table 7 does not include those from the 49,300 research documents with accession numbers 101<sup>a</sup> to 49,400 processed before 1973.

The six-volume Supplement II to the "Thermophysical Properties Research Literature Retrieval Guide" was just published in December 1979. The full reference citation for the Supplement II is as follows:

Thermophysical Properties Research Literature Retrieval Guide, Supplement II  
(1971-1977), Gerritsen, J.K., Ramdas, V., and Putnam, T.M. (Editors),  
Volumes 1 to 6, IFI/Plenum Data Co., New York, 1493 pp., 1979.

This six-volume Retrieval Guide Supplement II contains 57,108 codification entries on 14 thermophysical properties of 11,789 materials, citing 18,557

---

<sup>a</sup> Accession numbers 1 to 100 have not been assigned to any documents.

TABLE 6. STATISTICAL DATA ON THERMOPHYSICAL PROPERTIES COVERAGE OF THE WORLD LITERATURE<sup>a</sup>

<u>Material Group<sup>b</sup></u>	<u>No. of Materials as of 31 Dec. 1979</u>	<u>Property</u>	<u>No. of Codification Entries as of 31 Dec. 1979</u>
Elements and compounds	12,821	Thermal conductivity (including accommodation coefficient and thermal contact resistance)	77,105
Ferrous alloys	2,901	Specific heat	65,972
Nonferrous alloys	7,662	Viscosity	48,212
Mixtures and solutions	4,215	Thermal radiative properties	48,470
Systems and composites	2,820	Diffusion coefficient (to 1972)	28,780
Polymers, rubbers, etc.	737	Thermal diffusivity	6,752
Refractories, slags, glasses, and ceramics	2,055	Prandtl number	1,408
Natural products	1,055	Thermal linear and volumetric expansion	25,635
Minerals	1,053	Others	14,182
Applied Coatings	2,874		
Cermets	700		
Others	848		
Total	39,741	Total	316,516

Number of Documents Coded for Retrieval 77,058  
Number of Document Sources 8,630

<sup>a</sup> Systematic coverage retrospective to the year 1920 with earlier publications as far back as to the year 1822.

<sup>b</sup> These material groups are the same for both thermophysical and electronic properties.

TABLE 7. STATISTICAL DATA ON ELECTRONIC PROPERTIES COVERAGE OF THE WORLD LITERATURE<sup>a</sup>

<u>Material Group<sup>b</sup></u>	<u>No. of Materials as of 31 Dec. 1979</u>	<u>Property</u>	<u>No. of Codification Entries as of 31 Dec. 1979<sup>c</sup></u>
Elements and compounds	12,821	Absorption coefficient	8,629
Ferrous alloys	2,901	Dielectric constant	4,744
Nonferrous alloys	7,662	Dielectric strength	864
Mixtures and solutions	4,215	Energy bands	2,344
Systems and composites	2,820	Effective mass	1,409
Polymers, rubbers, etc.	737	Energy gap	5,574
Refractories, slags, glasses, and ceramics	2,055	Electric hysteresis	393
Natural products	1,055	Energy levels	6,240
Minerals	1,053	Electron emission properties	2,648
Applied Coatings	2,874	Electrical resistivity	39,925
Cermets	700	Magnetoelectric properties	2,278
Others	848	Hall coefficient	2,902
		Luminescence properties	3,613
		Magnetic hysteresis	2,670
		Mobility	3,214
		Magnetomechanical properties	976
		Magnetic susceptibility	7,292
		Photoelectronic properties	2,053
		Refractive index	5,918
		Thermoelectric properties	7,464
		Work function	1,839
		Piezoelectric properties	580
Total	39,741	Total	113,569

Number of Documents Coded for the New Retrieval System	27,024 <sup>c</sup>
Number of Document Sources	8,630

<sup>a</sup> Systematic coverage retrospective to the year 1950 with earlier publications as far back as to the year 1853.

<sup>b</sup> These material groups are the same for both thermophysical and electronic properties.

<sup>c</sup> Does not include 49,300 documents processed before 1973.



references with accession numbers up to 94,260 and with publication years to 1977. Table 8 gives the title, number of pages, and number of reference citations for each of the six volumes of Supplement II.

The four-volume Basic CINDAS Edition of the "Electronic Properties Research Literature Retrieval Guide," which covers the accumulated information since 1973, was just published in November 1979. The full reference citation for this publication is as follows:

Electronic Properties Research Literature Retrieval Guide, Basic CINDAS Edition (1972-1976), Chaney, J.F. and Putnam, T.M. (Editors), Volumes 1 to 4, IFI/Plenum Data Co., New York, 1604 pp., 1979.

This four-volume Retrieval Guide Basic CINDAS Edition contains 110,582 codification entries on 22 electronic, electrical, magnetic, and optical properties of 9,634 materials, citing 21,808 references with accession numbers up to 103,608 and with publication years to 1976. Table 9 gives the title, number of pages, and number of reference citations for each of the four volumes of the Basic CINDAS Edition.

TABLE 8. THERMOPHYSICAL PROPERTIES RESEARCH LITERATURE RETRIEVAL GUIDE,  
SUPPLEMENT II

(Covering the publication years 1971-1977)

	<u>No. of Pages</u>	<u>No. of Reference Citations</u>
Volume 1. Elements and Inorganic Compounds	508	8345
Volume 2. Organic Compounds and Polymeric Materials	188	1917
Volume 3. Alloys, Intermetallic Compounds, and Cermets	285	2703
Volume 4. Oxide Mixtures and Minerals	162	1651
Volume 5. Mixtures and Solutions	160	1571
Volume 6. Coatings, Systems, and Composites	190	2370
	<u>1493</u>	<u>18557</u>

TABLE 9. ELECTRONIC PROPERTIES RESEARCH LITERATURE RETRIEVAL GUIDE,  
BASIC CINDAS EDITION

(Covering the publication years 1972-1976)

	<u>No. of Pages</u>	<u>No. of Reference Citations</u>
Volume 1. Elements	502	8021
Volume 2. Inorganic and Intermetallic Compounds	621	8750
Volume 3. Alloys and Cermets	262	2839
Volume 4. Mixtures, Rocks and Minerals, Composites and Systems, Polymers	219	2198
	<u>1604</u>	<u>21808</u>

## SECTION III

### DATA TABLES ACTIVITIES

#### 1. DATA EXTRACTION AND COMPILATION

As a result of the systematic and comprehensive search of literature in the scientific documentation phase of this program described earlier, the original research documents of interest to TEPIAC are uncovered. These documents are procured and studied, from which the data are extracted, scrutinized, organized, converted to be in uniform units, and homogeneously plotted and tabulated in the form of "Tables of Original Data" which present all the available experimental data and information, as the first stage toward the preparation of internally consistent tables of critically evaluated "best data" referred to as "Tables of Recommended Reference Values." Subsequently, this information is reviewed and the organized data are given a final critical evaluation. At this second stage, the experimental data are analyzed, correlated, and synthesized, and the recommended values are generated. This two-stage data processing is found by TEPIAC to be the most logical approach lending itself to greater effectiveness in bringing to the user the results of this type of painstaking research in the shortest possible time.

The detailed procedures which TEPIAC follows in data compilation as well as in data analysis and synthesis are not necessarily a matter of established routines and do vary from property to property and from one group of materials to another. There are certain principles which must be followed, however, irrespective of the type of data or materials involved. For example: (a) the data should be extracted directly from their original sources to ensure freedom from errors of transcription; (b) the characterization and physical and chemical conditions of the test specimen should be specified as clearly as possible so as to fully identify the materials tested; (c) especially for solids, the source of the material, method of fabrication, thermal history, heat, mechanical, irradiative, and other treatments of the specimen and the measuring method and conditions should be noted; (d) if a comparative measurement method is used, the material used as comparative standard and its property values should be cited; (e) the accuracy and precision of the data reported should be separately denoted; (f) the complete reference to the original work should always be cited with the data; etc. Whenever some of the above criteria cannot be satisfied

because of absence of necessary information in the original work, an attempt is made to contact the author, if possible. In the cases where data cannot be adequately evaluated by TEPIAC due to lack of required information, such data are appropriately "flagged".

In connection with its activities in data processing, TEPIAC has established, through experience, appropriate procedures of operational practice which lend to good organization of work, uniform recording and filing, and other procedures of "good housekeeping," thus assuring ready tractability of original records of processed data, which are permanent working records for reference at any time in the future. Every effort has been made and all necessary steps have been taken to ensure that the data tables production rate is the maximum possible consistent with TEPIAC's high professional standards.

Within each data tables project there are four major tasks: (a) data extraction and compilation, (b) data evaluation, analysis, synthesis, and generation of recommended reference values, (c) text preparation, and (d) preparation of a manuscript for publication.

The statistical summary of accomplishments of the task on data extraction and compilation for all material properties are presented in Table 10, which shows that in this 12-month reporting period 2,148 research documents have been processed for data extraction, yielding 842 data source references, and 2,675 data sets have been compiled. These make a grand total of 44,855 research documents processed for data extraction, yielding 20,496 data source references, and TEPIAC has compiled a total of 93,713 data sets in its data file. It is important to note that data extraction and compilation is only one of the tasks and a small part of the total efforts.

TABLE 10. STATISTICAL SUMMARY OF ACCOMPLISHMENTS OF DATA EXTRACTION AND COMPILATION

	Total as of 31 Dec. 1978	This Period	Total as of 31 Dec. 1979
No. of documents processed	42,707	2,148	44,855
No. of documents accepted as data sources	19,654	842	20,496
No. of materials compiled	10,599	128	10,727
No. of data sets compiled	91,038	2,675	93,713

In many of the research documents data are presented in graphs only. More than ten years in the past a Gerber Electronic Digitizer had been used at TEPIAC to read data points off graphs. Recently the Gerber Digitizer has been replaced by a higher speed and more versatile Talos Electronic Digitizer/DEC Minicomputer-Data Processor for performing digitizing and more advanced data processing. The new equipment, which was purchased by funds provided by Purdue University, is in full operation. Whenever the graph is too small to give accurate readings, an attempt is made to contact the author for original data in tabular form.

## 2. DATA EVALUATION, CORRELATION, ANALYSIS, SYNTHESIS, AND GENERATION OF RECOMMENDED VALUES

Owing to the difficulties encountered in the accurate measurement of the properties of materials and in the adequate characterization of test specimens, especially solids, the property data recorded in the scientific and technical literature are often conflicting, widely diverging, and subject to large uncertainty. Indiscriminate use of literature data for engineering and design calculations without knowing their reliability is dangerous and may cause inefficiency or product failure, which at times can be disastrous. Consequently, only critically evaluated data should ever be used. Another important TEPIAC task is, therefore, to critically evaluate and analyze the available data and information, to give judgment on the reliability and accuracy of the data, and to generate recommended values.

The procedure involves critical evaluation of the validity of the data and related information, resolution and reconciliation of disagreements in conflicting data, correlation of data in terms of various controlling parameters, curve fitting with theoretical or empirical equations, comparison of results with theoretical predictions or with results derived from theoretical relationships or from generalized empirical correlations, etc. Besides critical evaluation and analysis of existing data, theoretical methods and semiempirical techniques are employed to fill data gaps and to synthesize fragmentary data so that the resulting recommended values are internally consistent and cover as wide a range of each of the controlling parameters as possible.

Considering the thermal conductivity data for example, in the critical evaluation of the validity and reliability of a particular set of experimental data, the temperature dependence of the data is examined and any unusual dependence

or anomaly is carefully investigated. The experimental technique is reviewed to see whether the actual boundary conditions in the measurement agreed with those assumed in the theoretical model used to define the property. It is ascertained whether all the stray heat flows and losses were prevented or minimized and accounted for. Furthermore, the reduction of data is examined to see whether all the necessary corrections were appropriately applied, and the estimation of uncertainties is checked to ensure that all the possible sources of errors, particularly systematic errors, were considered by the authors. Since the primary factor contributing to unreliable and erroneous experimental results is the systematic error in the measurement, experimental data can be judged to be reliable only if all sources of systematic error have been eliminated or minimized and accounted for. Major sources of systematic error may include unsuitable experimental method, poor experimental technique, poor instrumentation and poor sensitivity of measuring devices, sensors, or circuits, specimen and/or thermocouple contamination, unaccounted for stray heat flows, incorrect form factor, and, perhaps most important, the mismatch between actual experimental boundary conditions and those assumed in the theoretical model used to derive the value of thermal conductivity. These and other possible sources of errors are carefully considered in critical evaluation of experimental data. The uncertainty of a set of data depends, however, not only on the estimated error of the data but also on the adequacy of characterization of the material for which the data are reported.

Besides evaluating and analyzing individual data sets, correlation of data in terms of various controlling parameters is a valuable technique that is frequently used in data analysis. These parameters may include purity, composition, residual electrical resistivity or electrical resistivity ratio (if a metal), density or porosity, hardness, crystal axis orientation, degree of cold working, degree of heat treatment, etc. Applying the principle of corresponding states, reduced property values may be correlated with reduced temperature, pressure, and other reduced parameters.

Several properties of the same material can also be cross-correlated. For instance, thermal conductivity, specific heat, and density can be correlated with thermal diffusivity, and viscosity and specific heat of a gas can be correlated with thermal conductivity through the Chapman-Enskog theory or through the experimental data on the Prandtl number. For a fluid, the property of the saturated liquid can also be correlated with that of the saturated vapor.

It is important to note that irrespective of how much experimental data are available, reliable information exists only after the experimental data had been critically evaluated and recommended values generated. Figures 2 to 21 serve to illustrate this point. Figure 2 presents the experimental data and the recommended values on the thermal conductivity of titanium carbide and shows that the lower two sets of experimental data are utterly erroneous, being about five times too low at 800 K and ten times too low at 1350 K. Yet the lower two sets of data were published by an internationally well-known scientist and were obtained by using two completely different experimental methods for measurement. Titanium carbide has been extensively used to make machine tools. If machine tool designers blindly use the lower data for design without knowing that the data are erroneous, one can imagine the serious consequence.

Figure 3 presents the experimental data and the recommended values on the thermal conductivity of platinum (60%) + rhodium (40%) alloy. This figure shows that the higher experimental data are utterly erroneous, being about 140% too high at 550 K.

Figure 4 presents the experimental data and the recommended values on the thermal conductivity of tungsten and shows that most of the experimental data are erroneous, conflicting, and widely diverging. It has been estimated that the cost of experimental research (around 1968) was about \$30,000 per published research paper. Since the number of published papers reporting experimental results on the thermal conductivity of tungsten is larger than 100, a total of over \$3,000,000 research funds had been spent to produce the confusion of experimental data shown in Figure 4. It can apparently be seen from Figure 4 that it was not until TEPIAC critically evaluated the discordant experimental data and generated the recommended reference values that the true values of the thermal conductivity of tungsten were known.

Figure 5 presents the experimental data and the recommended values on the thermal diffusivity of tungsten. It shows that the lower three sets of data are utterly erroneous, being about five times too low. The recommended curve shown in the figure generated by TEPIAC not only indicates where the true thermal diffusivity values of tungsten are but also gives the values covering the full range of temperature, going far beyond the limited range covered by the experimental data.

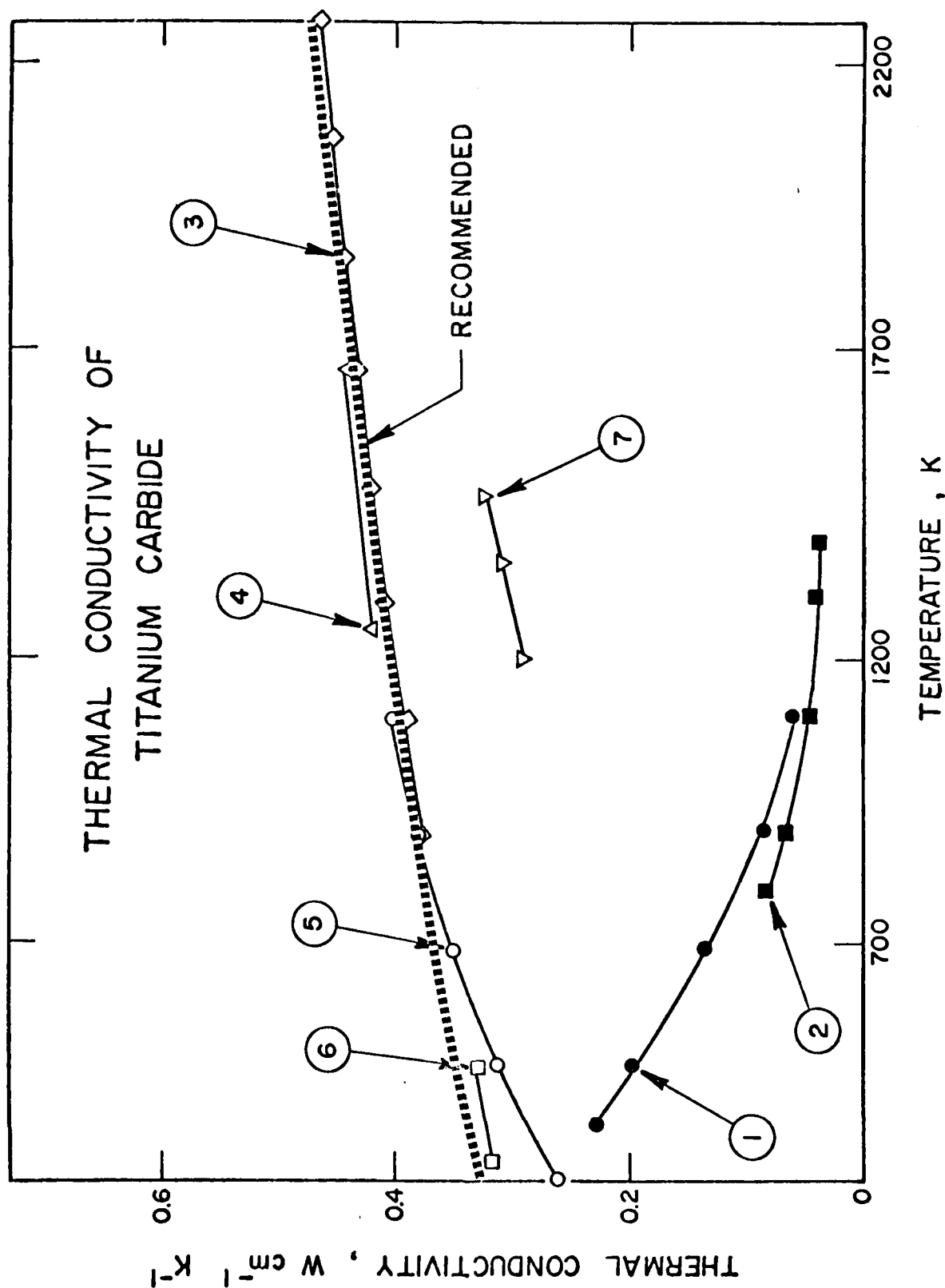


Figure 2. Experimental data and recommended values on the thermal conductivity of titanium carbide. This shows that the lower experimental data are utterly erroneous, being about five times too low at 800 K and ten times too low at 1350 K.



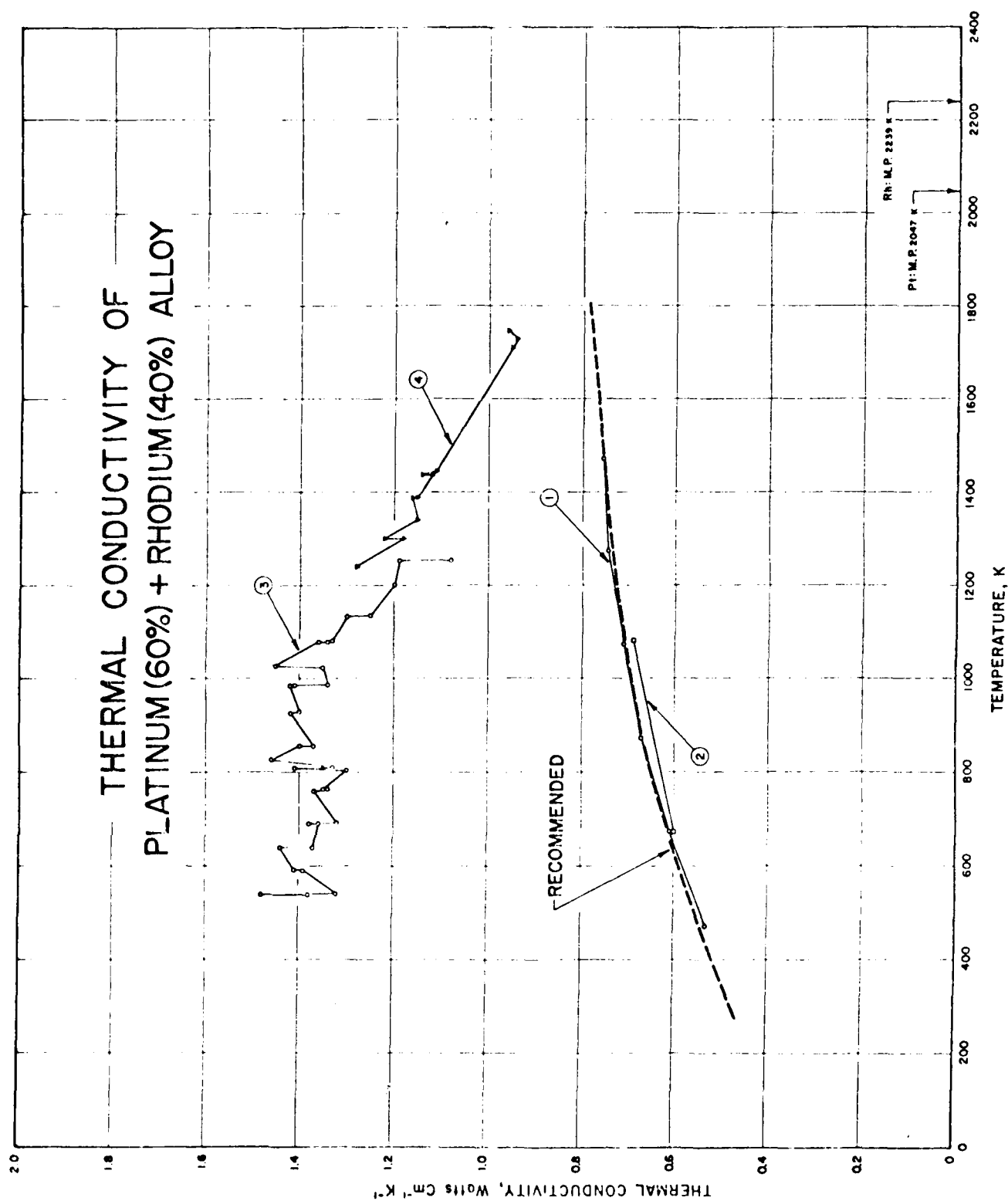


Figure 3. Experimental data and recommended values on the thermal conductivity of platinum (60%) + rhodium (40%) alloy. This shows that the higher experimental data are utterly erroneous, being about 140% too high at 550 K.

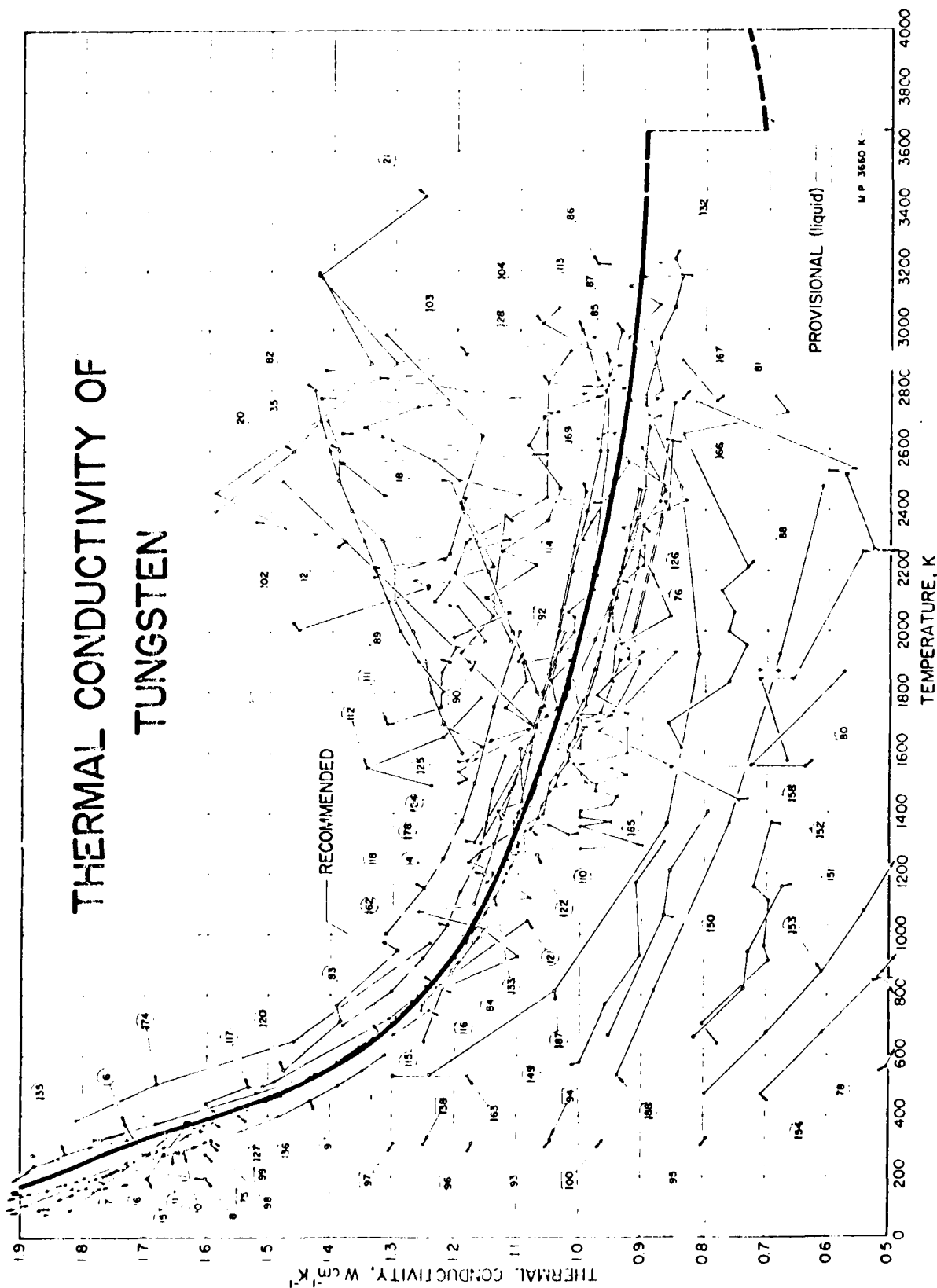


Figure 4. Experimental data and recommended values on the thermal conductivity of tungsten. This shows that most of the experimental data are erroneous, conflicting, and widely diverging.

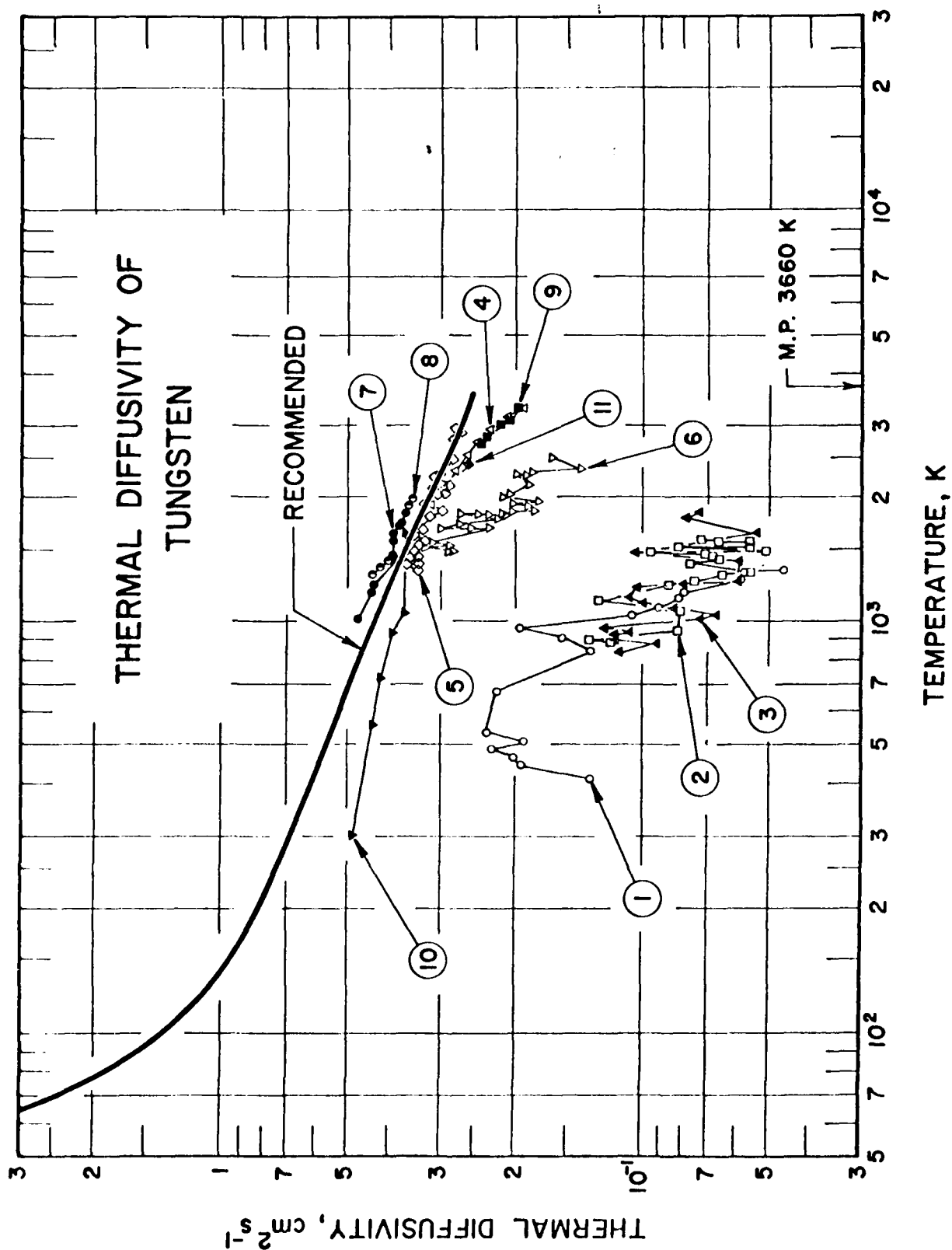


Figure 5. Experimental data and recommended values on the thermal diffusivity of tungsten. This shows that the lower experimental data are utterly erroneous, being about five times too low.

Figure 6 presents all the available experimental data on the thermal conductivity of aluminum + copper alloys, which are very limited, fragmentary, and conflicting. Through data evaluation, analysis, synthesis, and semi-theoretical calculations based on some of the data selected from those shown in Figure 6 and on the available data on the electrical resistivity, recommended values were generated which cover a full range of temperature and alloy composition as presented in Figure 7.

Figure 8 shows all the available experimental data on the absolute thermoelectric power of nickel + copper alloys, which are likewise very limited, fragmentary, and conflicting. Figure 9 presents the recommended values for the absolute thermoelectric power of nickel + copper alloys covering a full range of temperature and alloy composition, which were generated through critical evaluation, correlation, analysis, and synthesis of the limited experimental data shown in Figure 8.

The refractive index ( $n$ ) of alkali halides has received few measurements. Of the twenty alkali halides, sufficient data are available for only six. On a number of them only one single measurement has been made. The available information is even less for its temperature derivative ( $dn/dT$ ) and wavelength derivative ( $dn/d\lambda$ ). Only seven of the twenty alkali halides have received attention and no measurement has ever been made on thirteen of them. However, by using theoretical and semi-empirical techniques ingeniously in data analysis and synthesis, we were able to generate the refractive index and its temperature and wavelength derivatives for all the twenty alkali halides over the full wavelength range. Figure 10 shows the two experimental data points (the lower one of which is far off) available for the refractive index of lithium chloride and our recommended and provisional values which cover the full range of wavelength. No experimental data on the temperature and wavelength derivatives of the refractive index of lithium chloride are available, however we were able to generate predicted values for both of these two derivatives covering the full range of wavelength through correlation, prediction, and semi-theoretical calculation. Similar work has been done for the other alkali halides. In so doing we have generated recommended or predicted values for the refractive index, its temperature derivative, and its wavelength derivative of all the twenty alkali halides, which are shown respectively in Figures 11, 12, and 13.

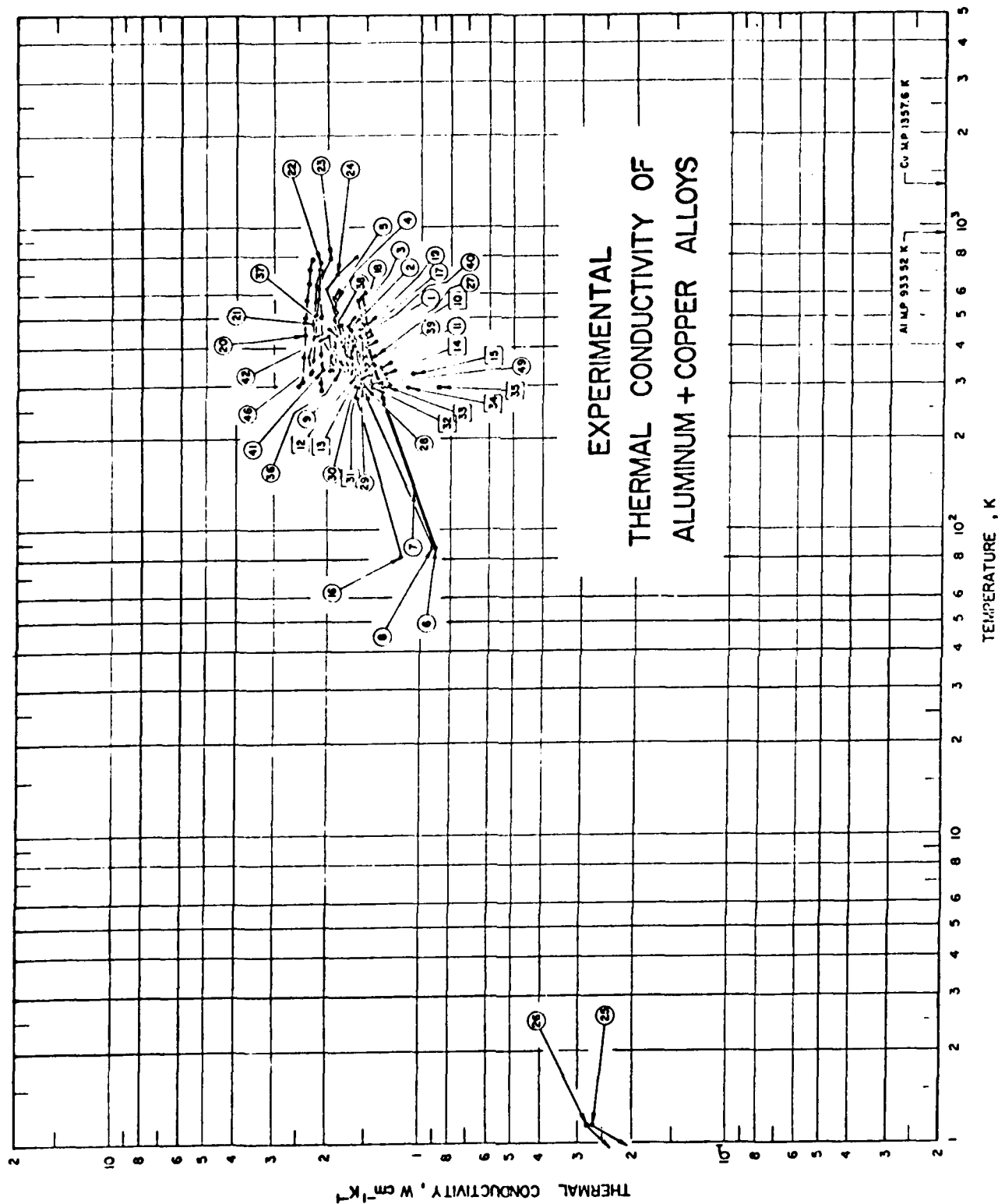


Figure 6. Experimental data on the thermal conductivity of aluminum + copper alloys. These experimental raw data are very limited, fragmentary, and conflicting.

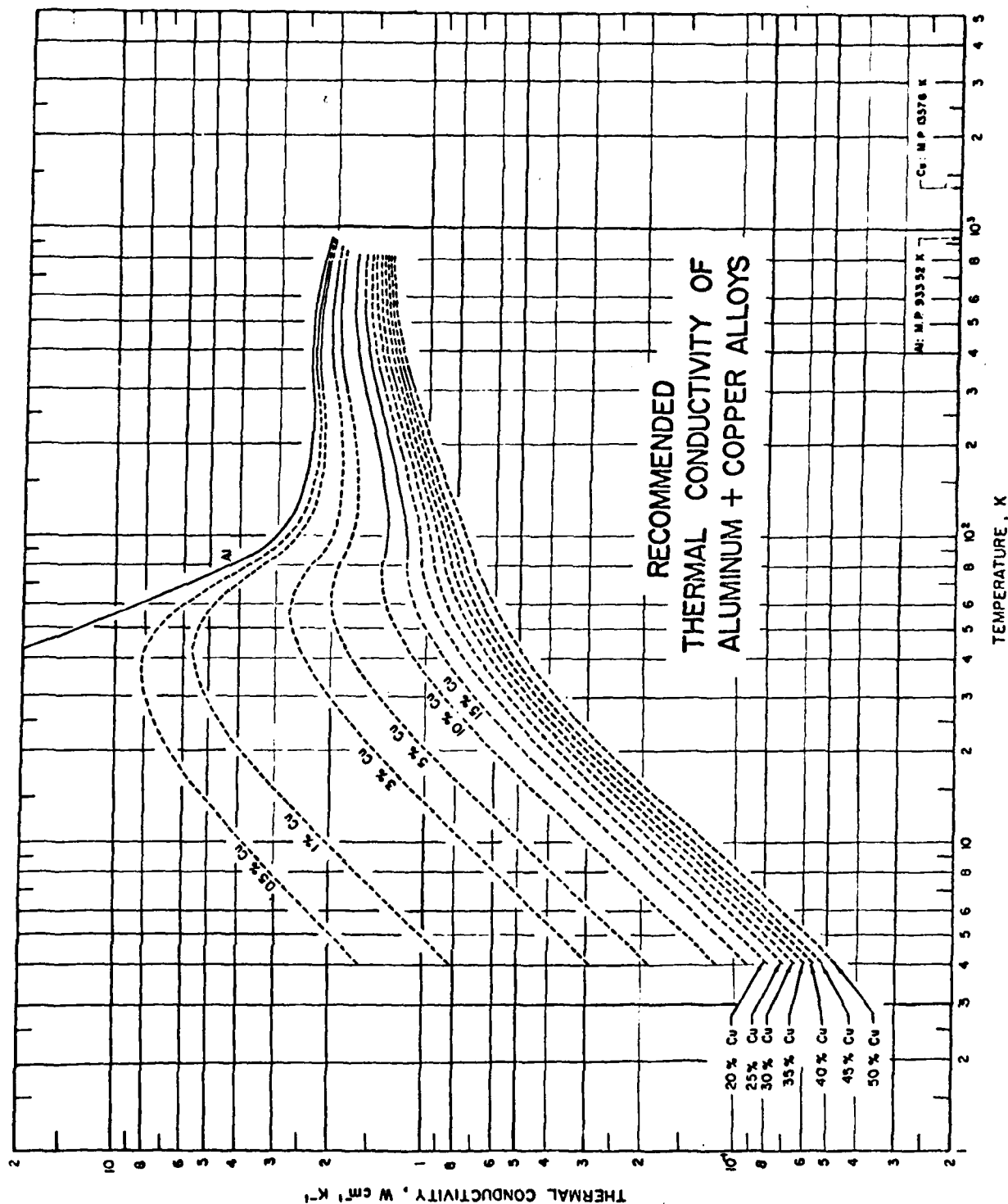


Figure 7. Recommended values for the thermal conductivity of aluminum + copper alloys. These recommended values are generated through data evaluation, analysis, synthesis, and semi-theoretical calculations based on the very limited experimental raw data shown in Figure 6 and on the available data on the electrical resistivity.

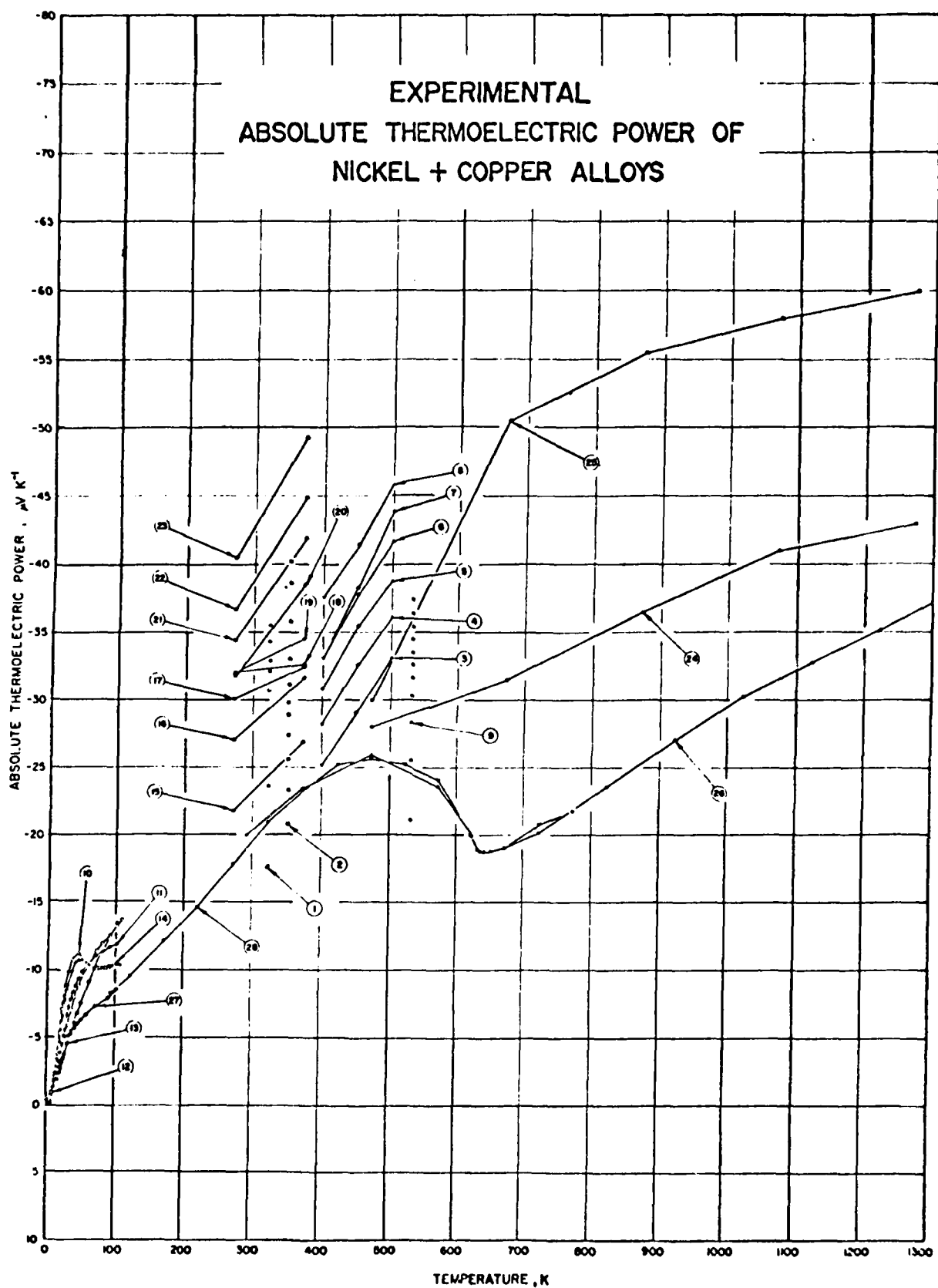


Figure 8. Experimental data on the absolute thermoelectric power of nickel+copper alloys. These experimental raw data are very limited, fragmentary, and conflicting.

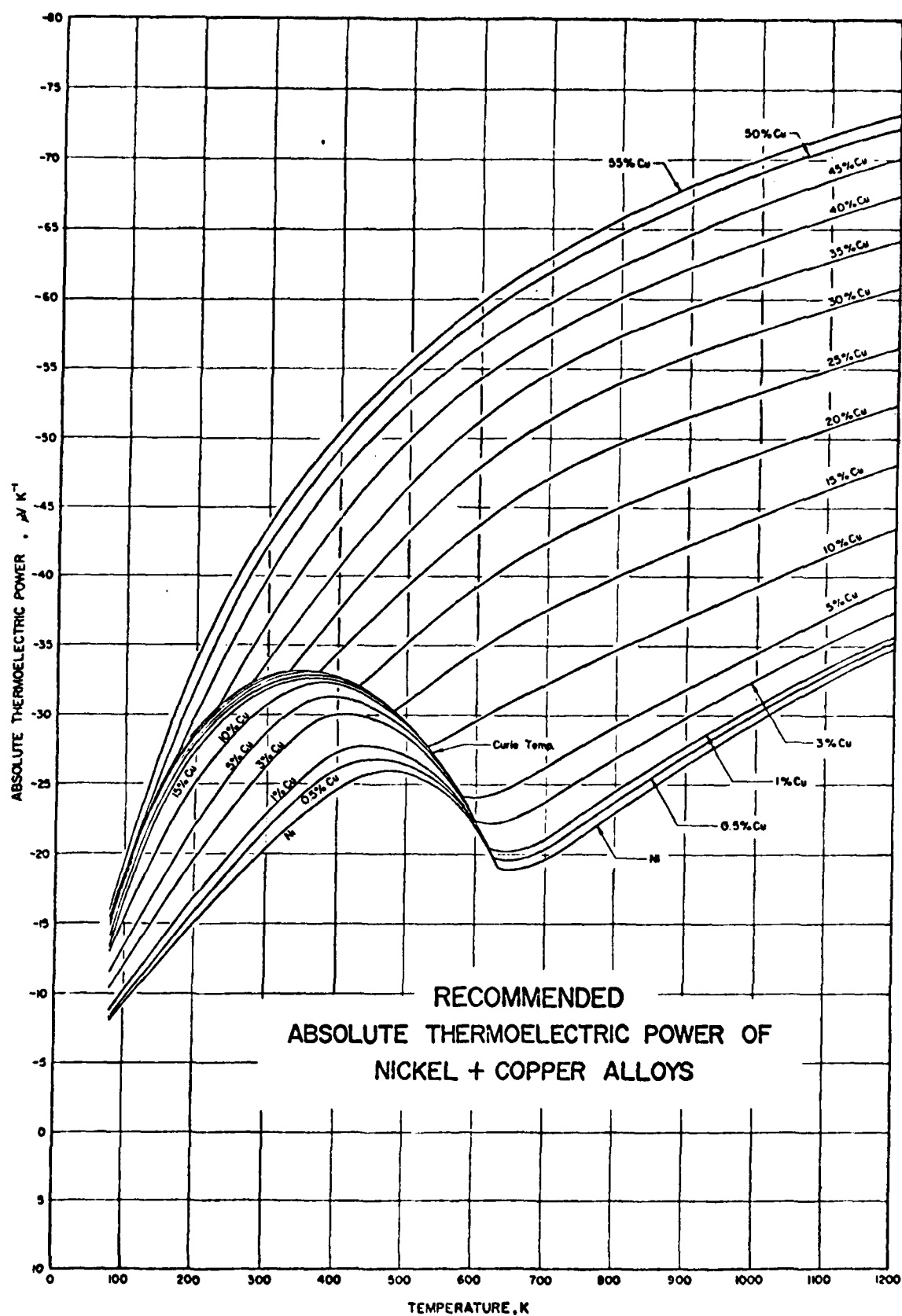


Figure 9. Recommended values for the absolute thermoelectric power of nickel+copper alloys. These recommended values are generated through data evaluation, correlation, analysis, and synthesis from the very limited experimental raw data shown in Figure 8.



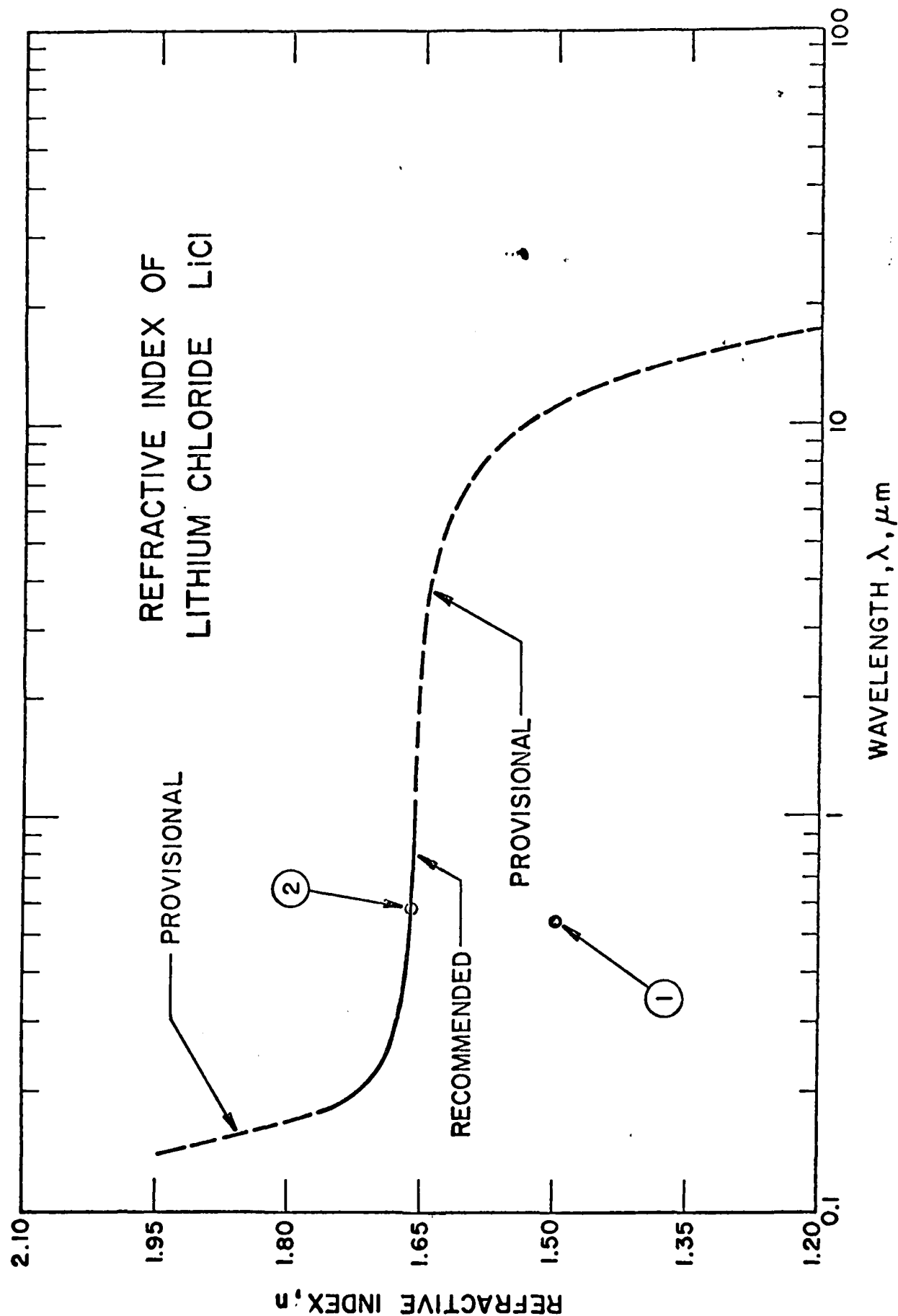


Figure 10. Experimental data and recommended and provisional values on the refractive index of lithium chloride. The lower experimental data point is far off. The full-range values are generated through data synthesis, correlation, and semi-theoretical calculation.

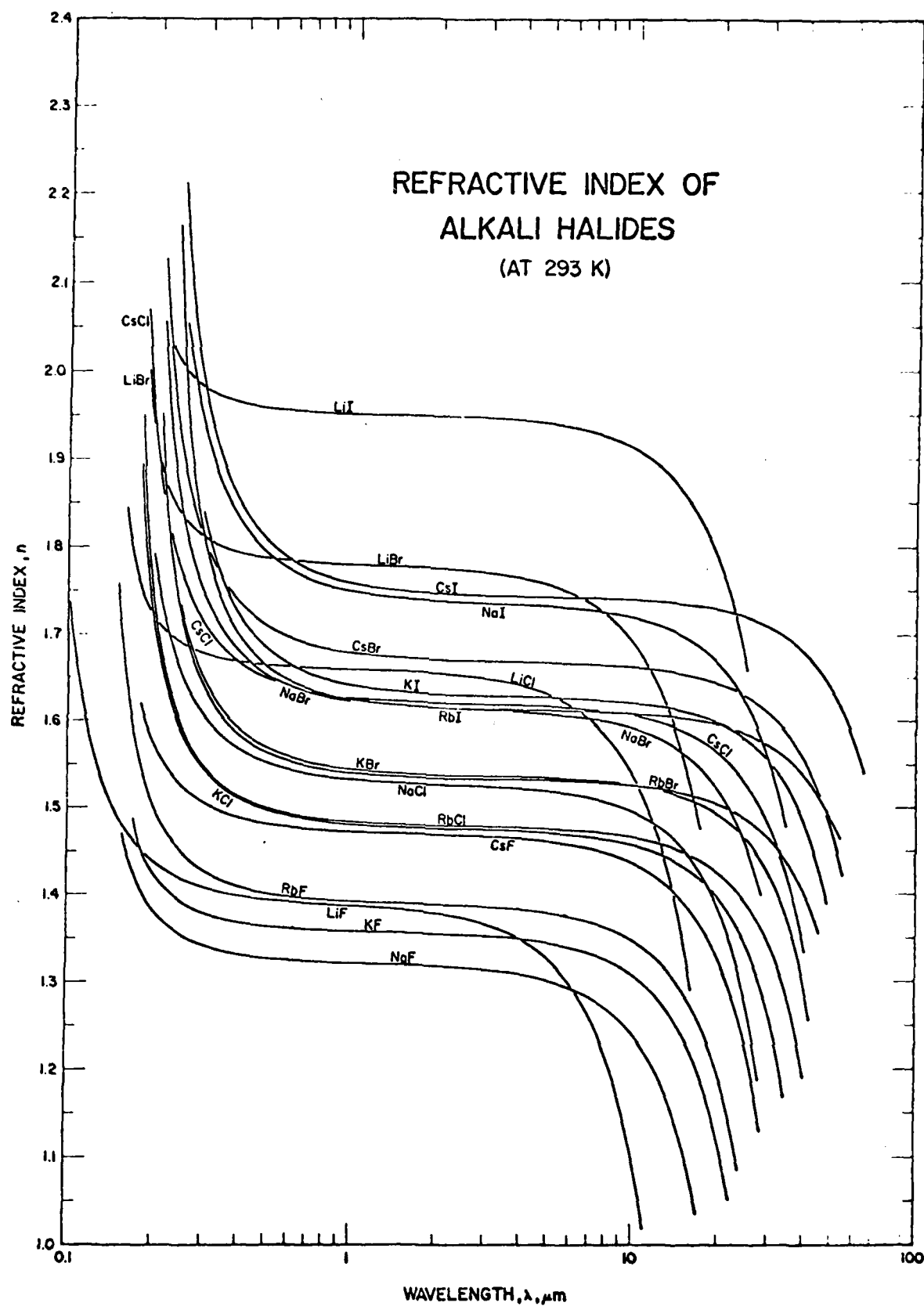


Figure 11. Recommended and provisional values for the refractive index of all twenty alkali halides. Most of the values are generated through synthesis, correlation, prediction, and calculation.

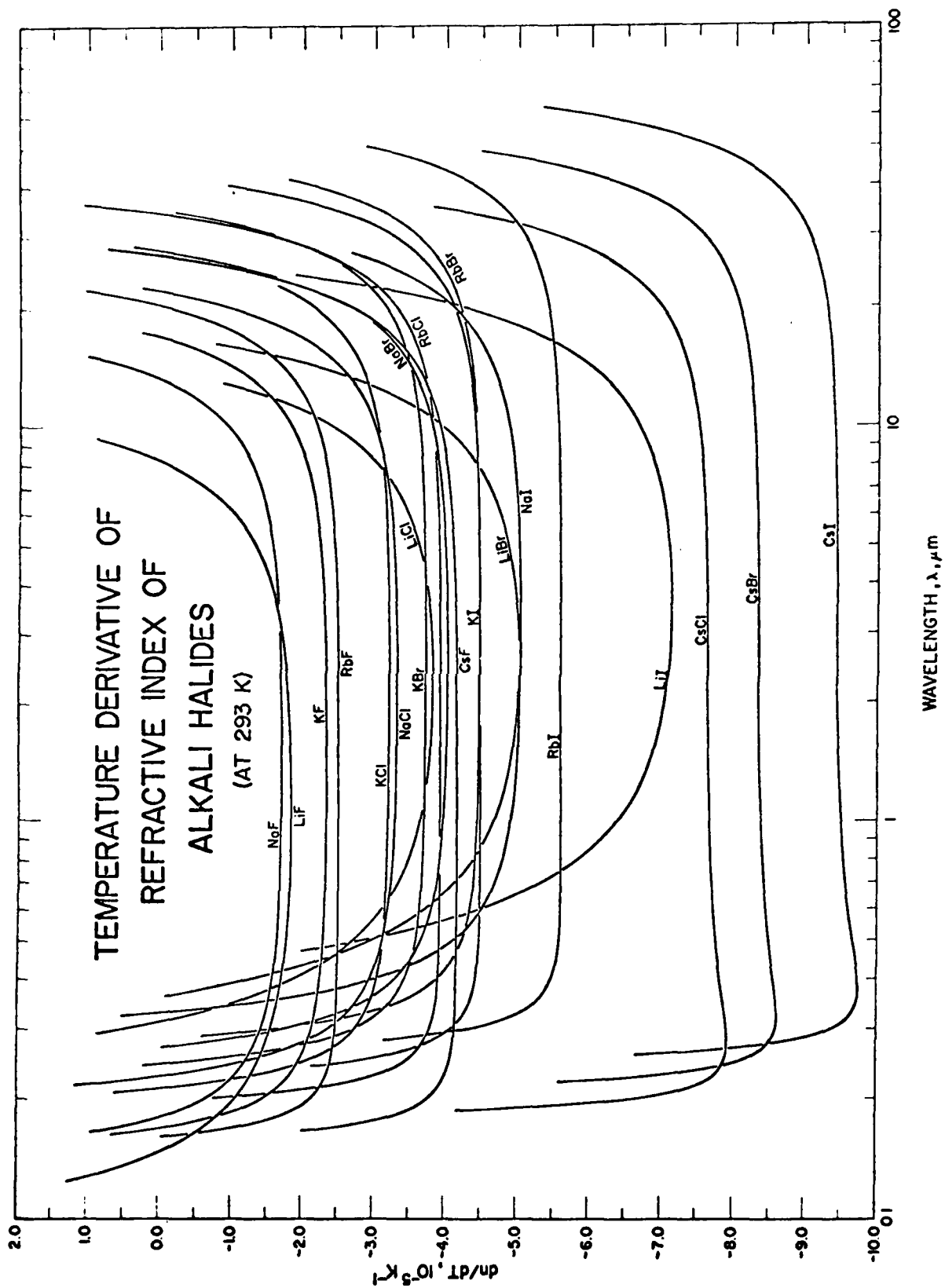


Figure 12. Recommended and provisional values for the temperature derivative of the refractive index of all twenty alkali halides. Most of the values are generated through correlation, prediction, and calculation.

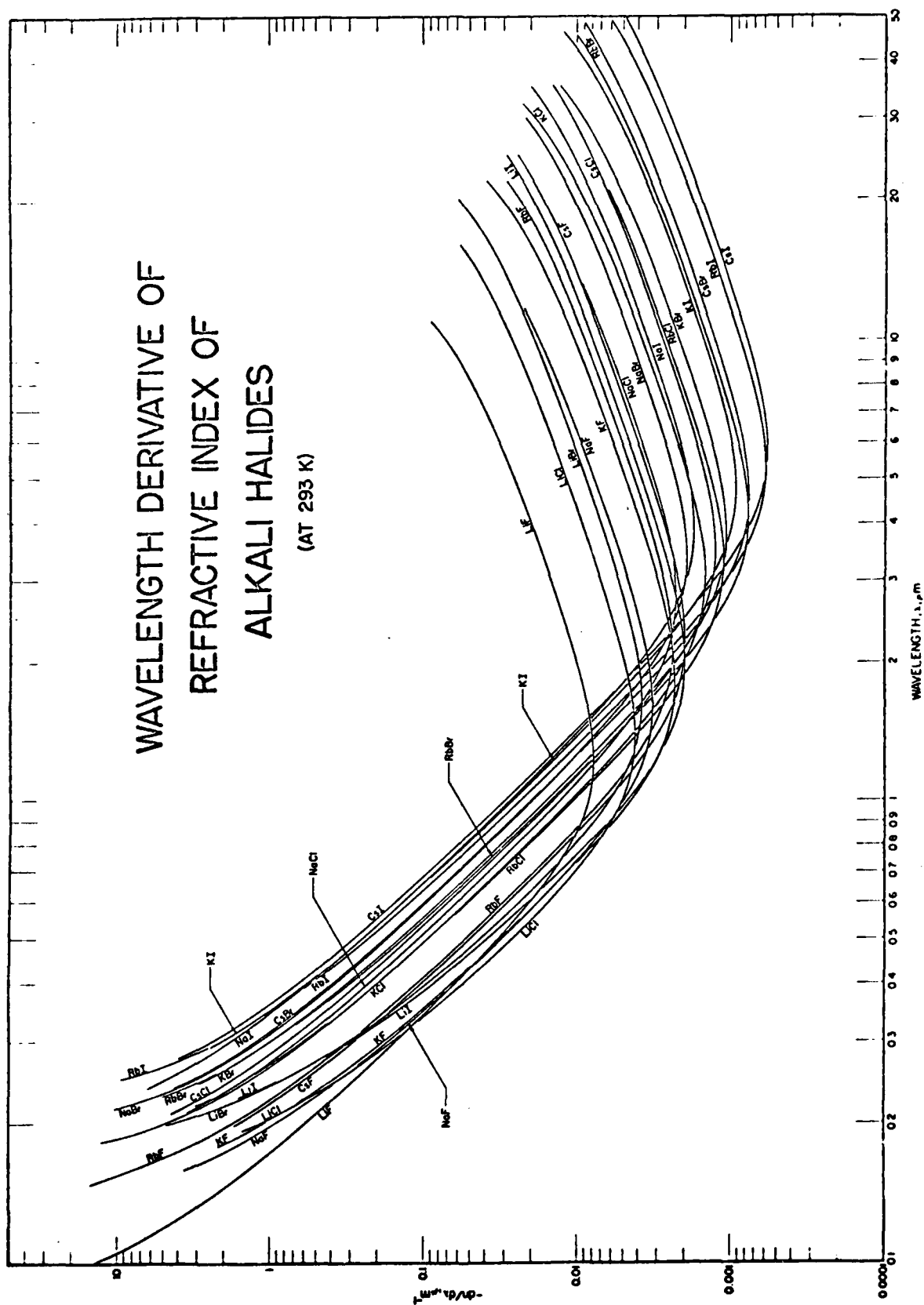


Figure 13. Provisional values for the wavelength derivative of the refractive index of all twenty alkali halides. Most of the values are calculated.

Figures 14 and 15 show all the available experimental data on the refractive index of silicon for the wavelength and temperature dependences, respectively. From these fragmentary and often conflicting data, recommended values were generated as presented in Figure 16 which cover a full range and are simultaneously as a function of both wavelength and temperature. Such a complete spectrum of values on the refractive index of silicon is for the first time ever available.

It should be apparent from the above illustrations that data evaluation, correlation, analysis, and synthesis is a very powerful tool which not only can clean up a body of conflicting and confusing data, but also can create new knowledge, which in itself is a major contribution to science and technology. Thus, TEPIAC can provide to the user not only just any (or all) available data and information (which is usually the limit that an ordinary information center can do), but the evaluated correct data and information, and furthermore, in many cases TEPIAC can provide predicted data and information to the user even when the required data and information are completely lacking and nonexistent. This is why TEPIAC has traditionally always stressed data evaluation, analysis, and synthesis and the generation of reference data.

### 3. HANDBOOKS AND DATA BOOKS<sup>a</sup>

The phenomenal growth of science and technology in recent decades has brought about a universal appreciation of the fact that the availability of adequate reference data for various properties of materials is essential to national progress, economy, and defense. To this end, TEPIAC has been contributing greatly through the generation of reference data tables and the design, preparation, publication, and maintenance of data books and handbooks, which is the principal means of satisfying user requirements for comprehensive and authoritative data and information on material properties.

The monumental 14-volume 16,810-page Thermophysical Properties of Matter - The TPRC Data Series has been completed and a summary of statistical data on the entire Data Series is presented in Table 11. For the user convenience and for promoting the sale of the Data Series, an index volume entitled Master Index to Materials and Properties for the TPRC Data Series was prepared. This Master Index lists alphabetically all the 6362 materials contained in the 13 volumes and give the volume number and page number for each property of each of the materials listed. This index volume has been published by IFI/Plenum Data Company and copies have been available for distribution since June 1979.

<sup>a</sup> The work on handbooks and data books has been jointly sponsored by DLA and other agencies and organizations.

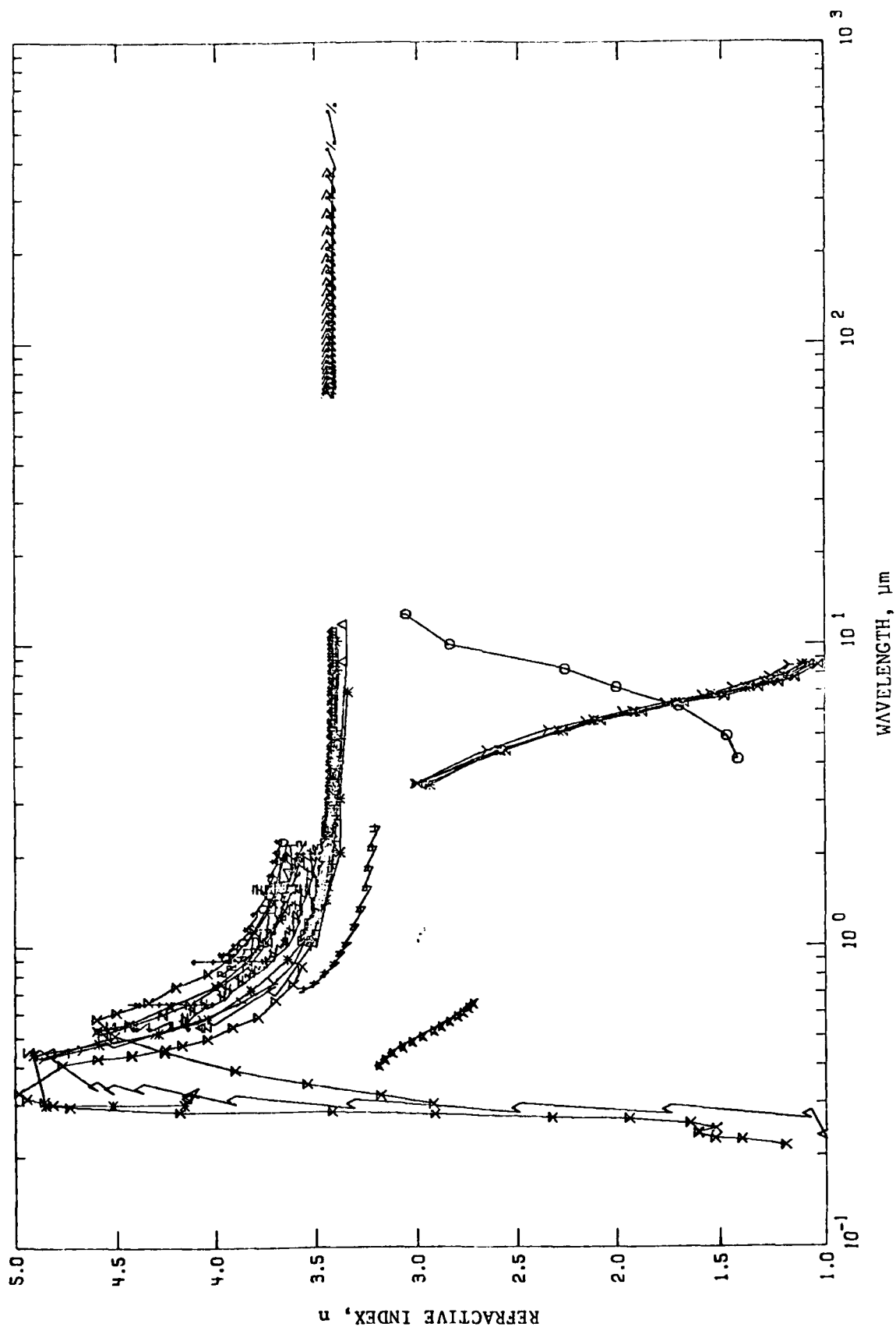


Figure 14. Experimental data on the refractive index of silicon (wavelength dependence).

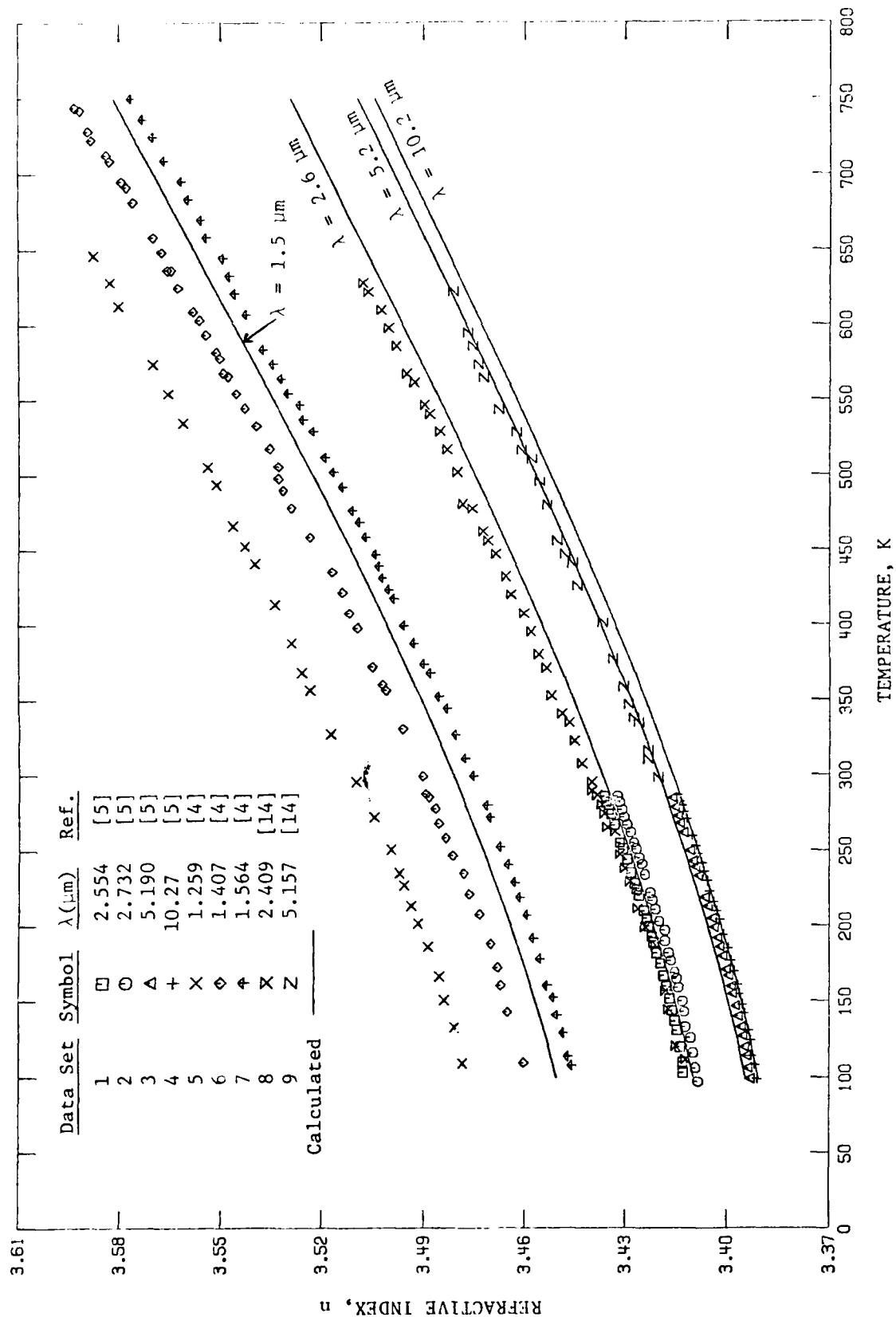


Figure 15. Experimental data on the refractive index of silicon (temperature dependence).  
Some calculated values are also shown for comparison.

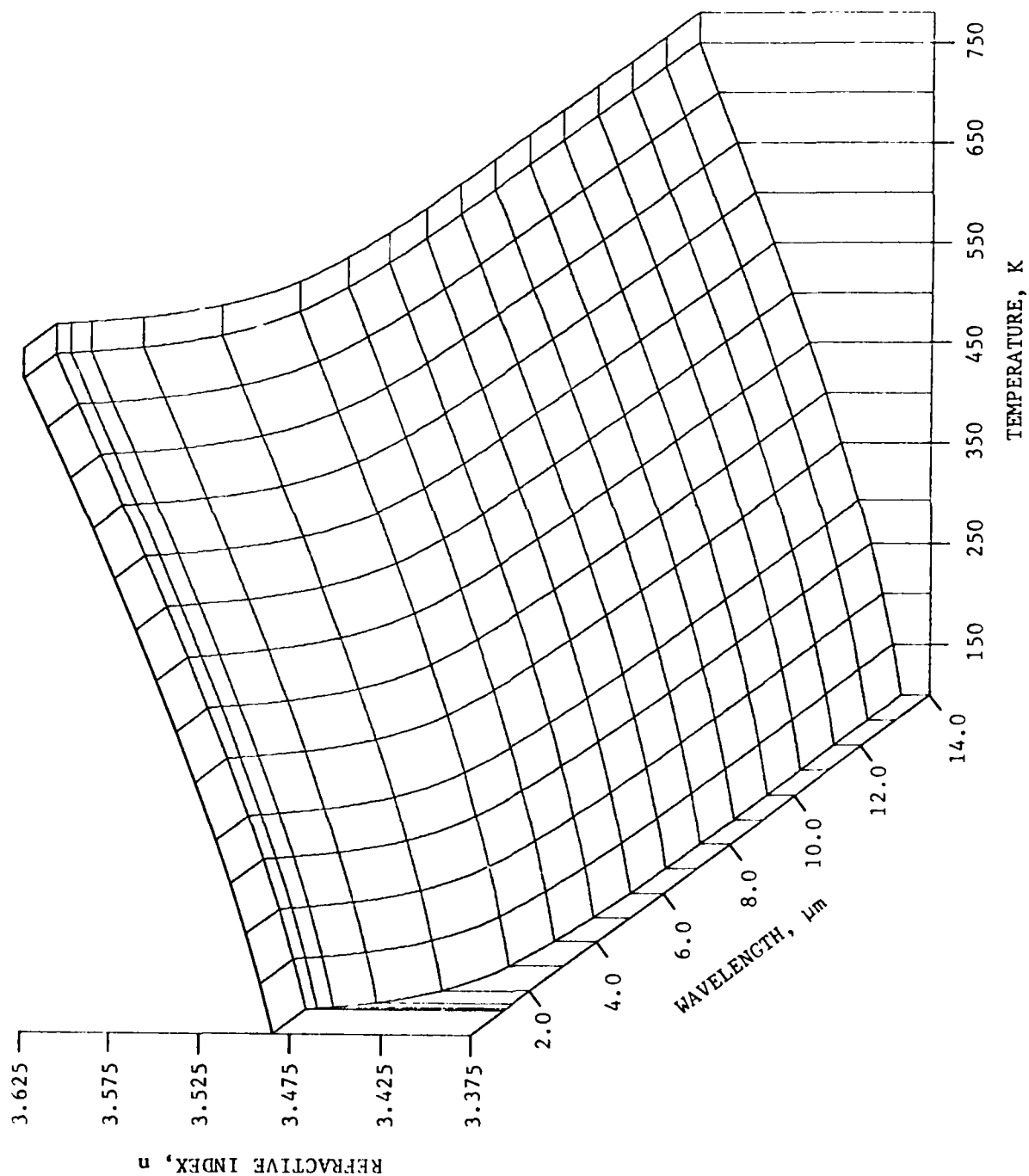


Figure 16. Recommended values for the refractive index of silicon as a function of both wavelength and temperature.



TABLE 11. SUMMARY OF STATISTICAL DATA ON "THERMOPHYSICAL PROPERTIES OF MATTER - THE TPRC DATA SERIES"

	<u>No. of Pages</u>	<u>No. of Data Sets</u>	<u>No. of Materials</u>	<u>No. of References</u>		
				<u>To Text</u>	<u>To Data Sources</u>	<u>Total</u>
Volume 1. Thermal Conductivity - Metallic Elements and Alloys	1595	5539	892	433	1013	1446
Volume 2. Thermal Conductivity - Nonmetallic Solids	1302	4627	812	439	598	1037
Volume 3. Thermal Conductivity - Nonmetallic Liquids and Gases	707	1505	170	681	725	1406
Volume 4. Specific Heat - Metallic Elements and Alloys	830	1186	322	61	428	789
Volume 5. Specific Heat - Nonmetallic Solids	1737	1009	550	61	457	518
Volume 6. Specific Heat - Nonmetallic Liquids and Gases	383	863	56	70	595	665
Volume 6 Supplement	169	726	307	0	878	878
Volume 7. Thermal Radiative Properties - Metallic Elements and Alloys	1644	5130	242	149	371	520
Volume 8. Thermal Radiative Properties - Nonmetallic Solids	1890	4971	782	121	455	576
Volume 9. Thermal Radiative Properties - Coatings	1569	5269	1161	180	295	475
Volume 10. Thermal Diffusivity	760	1733	445	253	315	568
Volume 11. Viscosity	801	1803	188	1218	377	1595
Volume 12. Thermal Expansion - Metallic Elements and Alloys	1440	4253	672	91	781	872
Volume 13. Thermal Expansion - Nonmetallic Solids	1786	4990	815	101	1112	1213
Index Volume. Master Index to Materials and Properties	197	----	6362	---	----	----
Total	16810	43604	----	3858	8400	12258

As the TPRC Data Series is completed, a new plan for the continuing data tables generation and publication with an even greater scope has been developed and is being implemented. In this plan, a new McGraw-Hill/CINDAS Data Series on Material Properties will be prepared and published. The structure of the new CINDAS Data Series had been revised three times since the initial conceptual presentation of it in 1977. At this time a realistic structure has been attained and it is contemplated that CINDAS Data Series will consist of some 42 volumes comprising approximately 14,000 pages. The revised structure and scope of the CINDAS Data Series is presented in Table 12. The revision of the structuring of the CINDAS Data Series has been mainly the combination of volumes previously conceived. For example, the previously conceived two volumes: one on "Non-stainless Alloy Steels" and the other on "Carbon Steels and Cast Irons" will be combined to become a larger volume entitled "Properties of Nonstainless Alloy Steels, Carbon Steels, and Cast Irons"; the completion of this new volume will actually be the completion of two volumes on alloys. The previously conceived volume on "Alloys of Hafnium, Molybdenum, Niobium, Tantalum, Titanium, Tungsten, and Zirconium" will combine with three other volumes on alloys to become a much larger volume entitled "Properties of Selected Transition-Metal Alloys," the completion of which will actually be the completion of four volumes on alloys.

Volumes in the new CINDAS Data Series will primarily be application (material) oriented, in contrast to the discipline (property) oriented structure of the old TPRC Data Series. In other words, each volume in the CINDAS Data Series will contain data on all the important physical properties of a group of materials, rather than containing data on only one property of many materials such as the volume in the old TPRC Data Series. In presenting the property data in each volume, all possible steps will be taken to reduce the bulk of the presentation by limiting the reporting to essential elements of information without sacrificing the information essential for scientific and technical usage of the data reported. In other words, the volumes will comprise mainly the recommended reference values or selected data.

Table 13 shows the properties to be covered by the volumes of the new CINDAS Data Series. The properties include eleven thermophysical and seven electrical, electronic, optical, and magnetic properties which are to be presented as a function of one or more variables such as temperature, pressure,

TABLE 12. STRUCTURE AND SCOPE OF "MCGRAW-HILL/CINDAS DATA SERIES ON MATERIALS PROPERTIES"

GROUP I. THEORY, ESTIMATION, AND MEASUREMENT OF PROPERTIES

- Volume I-1. Transport Properties of Fluids: Thermal Conductivity, Viscosity, and Diffusion Coefficient
- Volume I-2. Transport Properties of Solids: Thermal Conductivity, Electrical Resistivity, and Thermoelectric Properties
- Volume I-3. Specific Heat of Solids
- Volume I-4. Thermal Expansion of Solids
- Volume I-5. Thermal Radiative Properties of Solids

GROUP II. PROPERTIES OF SPECIAL MATERIALS

- Volume II-1. Thermal Accommodation and Adsorption Coefficients of Gases
- Volume II-2. Physical Properties of Rocks and Minerals
- Volume II-3. Optical Properties of Optical Materials
- Volume II-4. Thermal Radiative Properties of Coatings

GROUP III. PROPERTIES OF THE ELEMENTS

- Volume III-1. Properties of Selected Ferrous Alloying Elements  
(Cr, Co, Fe, Mn, Ni, and V)
- Volume III-2. Properties of Nonmetallic Fluid Elements  
(Ar, Br, Cl, F, He, H<sub>2</sub>, I, Kr, Ne, N<sub>2</sub>, O<sub>2</sub>, Rn, and Xe)
- Volume III-3. Properties of Selected Refractory Elements  
(Hf, Mo, Nb, Ta, Ti, W, and Zr)
- Volume III-4. Properties of Liquid Metal Elements  
(Li, Na, K, Rb, Cs, Fr, Hg, Ga, and In)
- Volume III-5. Properties of Selected Nonferrous Alloying Elements and Precious Metals  
(Al, Be, Cd, Cu, Pb, Mg, Sn, Zn, Au, Ir, Pd, Pt, Re, Rh, and Ag)
- Volume III-6. Properties of Rare-Earth and Radioactive Elements  
(Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Tc, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, and Lw)
- Volume III-7. Properties of Selected Semiconducting, Semimetallic, Nonmetallic Solid, and Other Elements  
(Ge, Po, Se, Si, Te, Sb, As, Bi, At, B, C, P, S, Ba, Ca, Os, Ru, Sr, and Tl)

GROUP IV. PROPERTIES OF ALLOYS AND CERMETS

- Volume IV-1. Properties of Stainless Steels
- Volume IV-2. Properties of Nonstainless Alloy Steels, Carbon Steels, and Cast Irons
- Volume IV-3. Properties of Selected Transition-Metal Alloys  
(Alloys of Cr, Co, Hf, Mn, Mo, Ni, Nb, Pd, Pt, Rh, Ta, Ti, W, U, V, and Zr)
- Volume IV-4. Properties of Selected Nontransition-Metal Alloys  
(Alloys of Al, Sb, Be, Bi, Cd, In, Pb, Mg, Sn, and Zn)
- Volume IV-5. Properties of Copper Alloys, Gold Alloys, and Silver Alloys
- Volume IV-6. Properties of Cermets

GROUP V. PROPERTIES OF FLUIDS AND FLUID MIXTURES

- Volume V-1. Properties of Inorganic and Organic Fluids
- Volume V-2. Properties of Commercial Refrigerants and Fluid Mixtures

GROUP VI. PROPERTIES OF OXIDES AND OXIDE MIXTURES

- Volume VI-1. Properties of Rare-Earth Oxides and Actinide Oxides  
(Oxides of Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ac, Th, Pa, U, Np, Pu, and Am)
- Volume VI-2. Properties of Electronic Oxides  
(Oxides of Cr, Co, Cu, Fe, Mn, Ni, Ti, V, and Zn)
- Volume VI-3. Properties of Selected Nontransition-Metal Oxides  
(Oxides of Al, Sb, Ba, Be, Bi, Cd, Ca, Cs, Fr, Ga, Ge, Au, In, Pb, Li, Mg, Hg, Po, K, Ra, Rb, Ag, Na, Sr, Tl, and Sn)
- Volume VI-4. Properties of Selected Transition-Metal Oxides and Oxides of Selected Nonmetallic Solid Elements  
(Oxides of Hf, Ir, Mo, Nb, Os, Pd, Pt, Re, Rh, Ru, Ta, Tc, W, Zr, As, B, P, Se, Si, and Te)
- Volume VI-5. Properties of Complex Oxides
- Volume VI-6. Properties of Oxide Mixtures
- Volume VI-7. Properties of Ceramics and Glasses

GROUP VII. PROPERTIES OF COMMERCIAL GRAPHITES, COMPOSITES, AND SYSTEMS

- Volume VII-1. Properties of Commercial Graphites and Carbon-Carbon Composites
- Volume VII-2. Properties of Composites  
(Other than Carbon-Carbon Composites)
- Volume VII-3. Properties of Systems

GROUP VIII. PROPERTIES OF NON-OXIDE INORGANIC COMPOUNDS AND INTERMETALLIC COMPOUNDS

- Volume VIII-1. Properties of Halides  
(Bromides, Chlorides, Fluorides, and Iodides)
- Volume VIII-2. Properties of Borides, Carbides, Hydrides, Nitrides, and Silicides
- Volume VIII-3. Properties of Arsenides, Phosphides, Selenides, Sulfides, and Tellurides
- Volume VIII-4. Properties of Carbonates, Nitrates, Phosphates, Silicates, and Sulfates
- Volume VIII-5. Properties of Intermetallic Compounds

GROUP IX. PROPERTIES OF POLYMERS, ORGANIC COMPOUNDS, FOODS, BIOLOGICAL MATERIALS, AND BUILDING MATERIALS

- Volume IX-1. Properties of Polymers
- Volume IX-2. Properties of Organic Compounds, Foods, and Biological Materials
- Volume IX-3. Properties of Building Materials

TABLE 13. PROPERTIES COVERED BY "McGRAW-HILL/CINDAS DATA SERIES ON MATERIAL PROPERTIES"<sup>a</sup>

I. PROPERTIES PRESENTED AS A FUNCTION OF ONE OR MORE VARIABLES

A. Thermophysical Properties

- |                             |   |
|-----------------------------|---|
| 1. Thermal Conductivity     | 7. Thermal absorptance                  |
| 2. Specific heat            | 8. Thermal transmittance                |
| 3. Thermal linear expansion | 9. Solar absorptance to emittance ratio |
| 4. Thermal diffusivity      | 10. Viscosity                           |
| 5. Thermal emittance        | 11. Prandtl number <sup>b</sup>         |
| 6. Thermal reflectance      |   |

B. Electrical, Electronic, Optical, and Magnetic Properties

- |                                      |   |
|--------------------------------------|---|
| 12. Electrical resistivity           | 15. Hall coefficient  |
| 13. Thermoelectric power             | 16. Optical constants (absorption index and refractive index) |
| 14. Dielectric constant <sup>c</sup> | 17. Magnetic susceptibility                                   |

II. PROPERTIES PRESENTED AS A SINGLE VALUE OR FOR ROOM TEMPERATURE

A. Thermophysical Properties

- |                                       |  |
|---------------------------------------|--|
| 18. Density (at NTP)                  | 24. Magnetic transition temperature        |
| 19. Normal melting point              | 25. Superconducting transition temperature |
| 20. Normal boiling point              | 26. Debye temperature (at T)               |
| 21. Triple point                      | 27. Heat of fusion (at NMP)                |
| 22. Critical temperature and pressure | 28. Heat of vaporization (at NBP)          |
| 23. Phase transition temperature      | 29. Vapor pressure (at T)                  |

B. Electrical and Electronic Properties

- |                         |                   |
|-------------------------|-------------------|
| 30. Dielectric strength | 32. Energy gap    |
| 31. Mobility            | 33. Work function |

C. Mechanical Properties

- |                                    |   |
|------------------------------------|---|
| 34. Elastic constants ( $c_{ij}$ ) | 42. Shear modulus                                   |
| 35. Tensile strength               | 43. Bulk modulus                                    |
| 36. Yield strength                 | 44. Poisson's ratio                                 |
| 37. Compressive strength           | 45. Hardness  |
| 38. Shear strength                 | 46. Toughness                                       |
| 39. Impact strength                | 47. Creep rate                                      |
| 40. Young's modulus                | 48. Velocity of sound (longitudinal and transverse) |
| 41. Compressive modulus            |   |

<sup>a</sup> Data on some of the properties are presented only for selected materials.

<sup>b</sup> Presented only for materials which are fluid at NTP.

<sup>c</sup> Presented only for long wavelengths ( $\lambda > 100 \mu\text{m}$ ).

wavelength, etc. and further include twelve additional thermophysical properties, four additional electrical and electronic properties, and fifteen mechanical properties which are to be given for room temperature or as single values. It is important to note that the properties covered include not only all the important thermophysical, electronic, electrical, magnetic, and optical properties but also all the important room-temperature mechanical properties. Although mechanical properties are outside the scope of TEPIAC, it is believed that the inclusion of a large number of mechanical properties (even with values given for room temperature only) would increase the usefulness of the volumes significantly.

By the end of 1979, the following four volumes of the new CINDAS Data Series have been completed:

Volume II-1. Thermal Accommodation and Adsorption Coefficients of Gases

Volume II-2. Physical Properties of Rocks and Minerals

Volume III-1. Properties of Selected Ferrous Alloying Elements

Volume III-2. Properties of Nonmetallic Fluid Elements.

Volume II-1 has 475 pages (xxxvi + 439) and contains 1182 references (655 references to text on thermal accommodation coefficient, 206 references to data on thermal accommodation coefficient, and 321 references to gas adsorption). In addition to giving a most comprehensive review and discussion of the theories, methods of measurement, and methods of calculation and prediction of the thermal accommodation coefficient and of the gas adsorption, this volume presents 591 sets of experimental data on the thermal accommodation coefficient of 159 solid-gas systems and presents or describes 288 sets of experimental results on the gas adsorption of 36 solid-gas systems.

Volume II-2 has 570 pages (xxii + 548) and contains 77 tables, 266 figures, and 1797 references (1111 cited references and 686 references listed in appendices). It covers 29 thermal, electrical, magnetic, physical, and mechanical properties and 116 types of rocks and 222 minerals. In addition to properties of rocks and minerals, this volume contains information and data also on the constitution of rocks and on the heat flow from the crust of the United States.

Volume III-1 has 284 pages (xv + 269) and contains 91 tables, 107 figures, and 1736 references. It presents data and information on 43 properties of six selected ferrous alloying elements, which are: chromium, cobalt, iron, manganese,

nickel, and vanadium. The 43 properties include 13 major properties which are presented as a function of one or more variables and 20 other properties which are given as a single value or for room temperature.

Volume III-2 has 224 pages (xv + 209) and contains 138 tables, 72 figures, and 269 references. It presents data and information on 15 properties of 19 nonmetallic fluid elements and isotopes, which are: argon, bromine, chlorine, deuterium, fluorine, helium-3, helium-4, normal hydrogen, ortho-hydrogen, para-hydrogen, iodine, krypton, neon, nitrogen, oxygen, ozone, radon, tritium, and xenon. The 15 properties include four major properties which are presented as a function of one or more variables and 11 others given as a single value or for room temperature.

The tables of contents of the four completed volumes of the new CINDAS Data Series reported above are given in Appendix 1 to show the scope of their coverage.

In 1979 another volume of data book entitled "Viscosity of Dense Fluids" was also completed. This volume is not in the CINDAS Data Series and was prepared in collaboration with two German scientists: Drs. K. Stephan and K. Lucas, who contributed technical work while TEPIAC provided bibliographic assistance, performed final editorial functions, and prepared the manuscript for publication. This volume has 280 pages (xii + 268), contains 376 references (166 references to text and 210 references to data sources), and presents 836 sets of recommended values (at 836 pressures) as a function of temperature for a total of 50 fluids. Additionally, this volume includes a review and discussion of the theories, methods of estimation, and techniques of correlation of the viscosity of dense gases and liquids. The table of contents of this volume is given in Appendix 2.

In addition to the work completed in 1979 as reported above, the work on Volume IV-1 entitled "Properties of Stainless Steels" has been in full progress, and in the meantime the works on the following six volumes have been initiated:

- Volume I-1. Transport Properties of Fluids: Thermal Conductivity, Viscosity, and Diffusion Coefficient
- Volume I-2. Transport Properties of Solids: Thermal Conductivity, Electrical Resistivity, and Thermoelectric Properties
- Volume I-3. Specific Heat of Solids
- Volume I-4. Thermal Expansion of Solids

Volume I-5. Thermal Radiative Properties of Solids

Volume VI-1. Properties of Rare-Earth Oxides and Actinide Oxides

#### 4. STATE-OF-THE-ART REPORTS, CRITICAL REVIEWS, AND TECHNOLOGY ASSESSMENTS

In order to keep abreast of the user needs in relation to high-interest technology and information, TEPIAC has prepared and issued state-of-the-art reports, critical reviews, and technology assessments, which are special technical reports resulted, respectively, from comprehensive studies, extensive critical reviews, and short comparative assessments of current high-interest technology and information.

In this 12-month reporting period two major technical reports were completed, which are as follows.

- (1) "Refractive Index of Silicon and Germanium and Its Wavelength and Temperature Derivatives," Purdue University, CINDAS Report 53, 132 pp., 1979.

This report contains the most comprehensively compiled experimental data and information on the refractive index of silicon and germanium and its wavelength and temperature derivatives, and presents also the recommended values resulted from the critical evaluation, analysis, and synthesis of the available data. Calculated values are given wherever experimental data are not available. The recommended values for the refractive index of silicon cover the range 1.2 to 14  $\mu\text{m}$  and 100 to 750 K and those of germanium cover the range 1.9 to 16  $\mu\text{m}$  and 100 to 550 K. Silicon and germanium are extremely important materials to the Defense community and have found numerous Defense applications in both infrared optics and electronics. They are also used in solar cells and thermoelectric devices to generate power for military satellites and other applications. Among the properties of silicon and germanium, the refractive index covered in this report plays a decisive role in the optical performance of the material, particularly in the design of infrared optical systems. Silicon and germanium are also brought into consideration for military high-power laser applications due to their high optical figure of merit, great mechanical strength, high chemical resistance, and availability in large size, even though their absorption coefficient at laser wavelengths is relatively high.

- (2) "Thermophysical and Electrical Properties of Metal Matrix Composites," Purdue University, CINDAS Report 56, 264 pp., 1979.

This report presents the available experimental data and information on the thermophysical and electrical properties of 38 metal matrix composites, which are organized into eight groups according to the various metals constituting the matrices of the composites. Although the literature search was aimed at seeking data for all the thermophysical and electronic properties of all the metal matrix composites, data were found for only five properties. These are the thermal linear expansion, thermal conductivity,



specific heat, thermal emittance, and electrical resistivity. The eight groups of metal matrix composites for which data were found are the various composites of aluminum and aluminum alloy matrices, copper matrix, lead matrix, magnesium matrix, nickel and nickel alloy matrices, titanium and titanium alloy matrices, tungsten matrix, and zinc matrix.

Three of the technical reports prepared previously for AMMRC and DLA have been published in this reporting period as formal publications in a well-known scientific journal. The three formal publications are:

- (a) "Electrical Resistivity of Alkali Elements," Journal of Physical and Chemical Reference Data, 8(2), 339-438, 1979. [Originally CINDAS Report 40]
- (b) "Electrical Resistivity of Alkaline Earth Elements," Journal of Physical and Chemical Reference Data, 8(2), 439-497, 1979. [Originally CINDAS Report 42]
- (c) "Electrical Resistivity of Copper, Gold, Palladium, and Silver," Journal of Physical and Chemical Reference Data, 8(4), 1147-1298, 1979. [Originally CINDAS Report 46]

#### 5. CARBON-CARBON COMPOSITES DATA BANK

The primary objective of this special project is to develop and establish a numerical data bank on the physical properties of carbon-carbon composites. This project is conducted in conjunction with MCIC/Battelle and the carbon-carbon composites are limited to a number of selected specific types. The responsibility of TEPIAC in this project is to cover the following five thermo-physical properties:

- (1) Thermal conductivity
- (2) Specific heat
- (3) Thermal expansion
- (4) Thermal diffusivity
- (5) Thermal radiative properties.

In addition to the data on specific types of carbon-carbon composite materials, data on carbon felt-type insulations are also of interest to this project.

At the beginning of this project, a thorough search through TEPIAC files for pertinent references was conducted and special retrospective searches were also conducted for TEPIAC by NTIS, DDC, and the Smithsonian Information Center at our request. A complete list of "Data Recording Parameters for Thermophysical Properties" was developed and subsequently was incorporated into the computer file structure for input of data into the data bank.

As data on the selected specific types of carbon-carbon composites and carbon felt-type insulations became available, they were extracted and carefully recorded according to the established format, and keyboarded for entry into the carbon-carbon composites data bank. So far 207 sets of data have been keyboarded and transmitted to Battelle for entry into the data bank.

In addition to the processing of data, descriptions of the experimental methods used by Southern Research Institute for measurements of the thermal linear expansion and the thermal conductivity for the PAN Pilot Production Program were prepared and revised. Study of the report by Fiber Materials, Inc. on Seven-Inch Man-Tech Billet Program was begun. One pertinent fact discovered was the mismatch in the thermal linear expansion data between the low-temperature and high-temperature data sets. Work was also initiated to reconstruct the P4 data using the established format developed by TEPIAC.

TEPIAC gave a status report on the thermophysical properties for the carbon-carbon composites data bank at the TI/TD meeting on November 28, 1979, held at Battelle Columbus Laboratories.

#### 6. COMPUTERIZED NUMERICAL DATA STORAGE AND RETRIEVAL SYSTEM

Although TEPIAC has possessed a fully computerized bibliographic information storage and retrieval system capable of instant retrieval of all kinds of bibliographic information, the computerized numerical data storage and retrieval system is still under development. The development of this numerical data system was supported mainly through other sources.

This computerized numerical data storage and retrieval system will comprise two data files (data banks): one on evaluated numerical data (recommended values) and the other on unevaluated numerical data (raw experimental data).

For the evaluated numerical data bank, the overall design of the data bank and of the data capturing scheme had long been completed and the computer programming for storing the data has been finished. However, much remains to be done, especially in the computer programming phase of data retrieval and manipulation. Evaluated data extracted from seventeen data source references have been stored on magnetic tapes in this data bank, which currently contains 4,268 evaluated data sets (comprising 69,439 data points) on 15 properties of 1,764 materials. For the unevaluated numerical data bank no work has yet been done. This development work has been halted pending the continuation of funding.

This computerized numerical data system, when completed, should eventually be able to perform at least the following functions:

- (1) Store and retrieve recommended reference data together with information on material identification and characterization and on data uncertainty.
- (2) Store and retrieve experimental data together with information on specimen specification and characterization and on measurement method and condition.
- (3) Manipulate data for data analysis, correlation, derivation, curve fitting, etc.
- (4) Prepare tables, graphs, and list of references by computer for publication and for answering technical inquiries.
- (5) Search for materials with given ranges of values of various properties.
- (6) Be used for on-line computer search.

## SECTION IV

### INQUIRY SERVICES

TEPIAC's day-by-day contributions in inquiry services to individual users have been primarily in the nature of specialized advisory and technical consulting, data recommendation and prediction, and special bibliographic and data searches. During this 12-month reporting period 562 inquiries have been responded, of which 462 came from 44 states and the District of Columbia and 100 from 26 foreign countries. It is noted also that 69 of the 562 inquiries came from government laboratories and agencies, 136 from academic institutions, and 357 from defense contractors and other industrial organizations. Detailed statistical summary of inquiry responses for 1979 is presented in Table 14. Table 15 shows the geographical distribution of inquiry responses for 1979. A summary of inquiry responses for the last 17 years since 1963 is presented in Figure 17.

Over the years TEPIAC has developed a most efficient way for responding to technical and bibliographic inquiries. This is the result of our efficient "User Service Control System," which is based on the concept of having one staff member to be responsible for centralized control and coordination of requests and responses and using the contributions from various staff members whose expertises are in the areas of the requests. Furthermore, in order to expedite the service, TEPIAC accepts authorization for requests for normal technical and bibliographic inquiries by telephone as well as by letter or purchase order. All technical inquiry responses are recorded by the serial number, date, analyst (persons contributing to answering query), total hours, subject code, fee charged or service code, user codes, and mailing address. These recorded data are very useful for user service control and are also reported to the sponsor in the Quarterly R & D Contract Status Reports.

In order to assess the usefulness of TEPIAC's inquiry service and the degree of user satisfaction, a short questionnaire is sent to each inquirer together with the inquiry response (see Appendix 3 for a copy of TEPIAC Technical Inquiry Questionnaire). It should be noted that this simple questionnaire can be easily and quickly filled out by simple checks or short answers to questions. The information from the returned questionnaire is used as a feedback to our User Service Control System for constantly improving the quality of TEPIAC's inquiry service.

TABLE 14. STATISTICAL SUMMARY OF INQUIRY RESPONSES FOR 1979

	Information Request	Publication Request	Technical Question <sup>a</sup>	Bibliographic Search	TOTAL
<u>DOMESTIC</u>					
Government	18	2	24	7	51
Industry	99	33	125	56	313
University	<u>29</u>	<u>16</u>	<u>37</u>	<u>16</u>	<u>98</u>
Subtotal	146	51	186	79	462
<u>FOREIGN</u>					
Government	9	4	5	0	18
Industry	19	13	12	0	44
University	<u>15</u>	<u>15</u>	<u>7</u>	<u>1</u>	<u>38</u>
Subtotal	43	32	24	1	100
TOTAL	189	83	210	80	562

<sup>a</sup> Including data analysis and technical review.

Between 1 July 1977 and 31 December 1979, 1281 questionnaires were mailed out with our responses to inquirers. A total of 328 completed questionnaires were returned to TEPIAC. The rate of return was an outstanding 25.6 percent; most survey researchers would consider a 10 percent return to be excellent. The survey results from these returned questionnaires are presented in Appendix 4. It is very encouraging to note from the survey results that 18 percent of the users of TEPIAC technical inquiry services were "repeat customers". Note also that another 26 percent users were aware of TEPIAC through their co-workers, who must have given to them good recommendations about TEPIAC. Most users were pleased with TEPIAC responses to their inquiries, as 51% users rated the TEPIAC responses to be "very good," 38% users rated the responses to be adequate, while only 11% users considered the responses to be of marginal value. About 94% of the replies rated the TEPIAC inquiry service as prompt and 95% rated the charges reasonable, and only 4% considered the charges to be too high and 1% considered the charges too low. Perhaps the most important information obtained from these questionnaires was the value of the TEPIAC responses to the users. The survey results indicate that 39 percent of the responses saved the users 5 hours or less (these include the responses informing the users that no data/information

TABLE 15. GEOGRAPHICAL DISTRIBUTION OF INQUIRY RESPONSES FOR 1979

	No. of Inquiries
Alabama	9
Arizona	6
California	71
Colorado	10
Connecticut	10
Delaware	1
District of Columbia	15
Florida	5
Georgia	5
Hawaii	1
Idaho	3
Illinois	20
Indiana	25
Iowa	2
Kansas	1
Kentucky	2
Maine	1
Maryland	15
Massachusetts	24
Michigan	12
Minnesota	6
Mississippi	1
Missouri	5
Montana	2
Nevada	1
New Jersey	19
New Hampshire	1
New Mexico	10
New York	35
North Carolina	4
North Dakota	4
Ohio	36
Oklahoma	3
Oregon	4
Pennsylvania	26
Rhode Island	3
South Carolina	2
South Dakota	1
Tennessee	13
Texas	16
Utah	5
Virginia	12
Washington	8
West Virginia	1
Wisconsin	3
	462
Foreign Countries	100
TOTAL	562

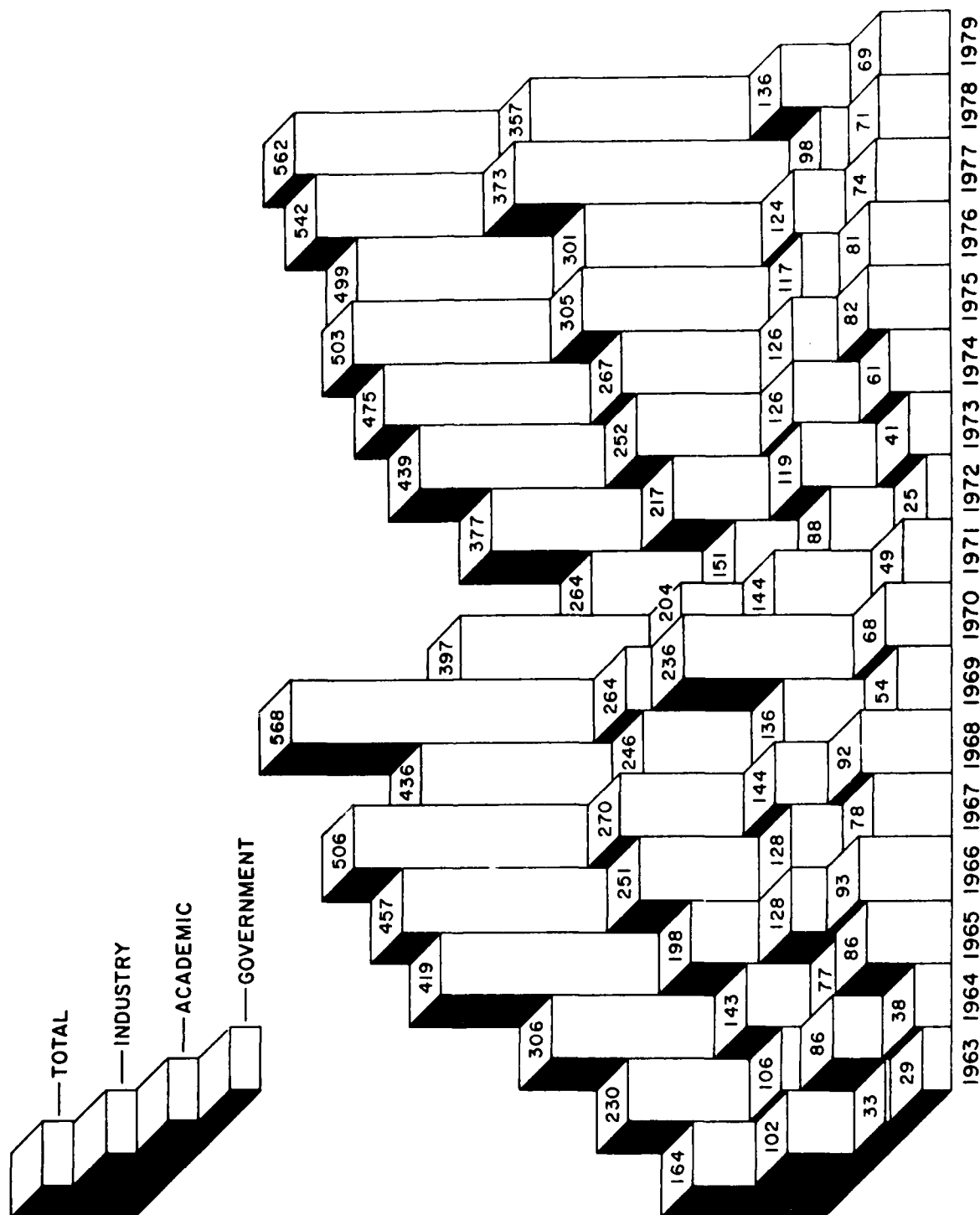


Figure 17. Summary of inquiry responses since 1963.

are uncovered from our exhaustive search for the properties of materials requested), 26 percent of the responses saved the users 40 hours or more, 14 percent of the responses saved the users 20 to 10 hours, another 14 percent saved the users 10 to 5 hours, and 7 percent of the responses saved the users 30 to 20 hours. Those larger savings (far exceeding 40 hours) were from inquiry responses that provided the users with numerical property data rather than bibliographic information. Typical comments of users on TEPIAC inquiry services are also listed in Appendix 4.

It is important to note that even though TEPIAC has provided excellent inquiry services to the users, these services impart only a relatively small portion of the total information and data that TEPIAC has provided to the users. The major portion of the information and data are provided to the users through TEPIAC's major publications. For example, two users commented "we are regularly using Volumes 1-13 of the Thermophysical Properties of Matter - The TPRC Data Series; these volumes are extremely useful in our research". Of course, there are numerous other unreported cases where users use the data and information contained in this and other major publications of TEPIAC. Consider this 13-volume 16,810-page TPRC Data Series alone, of which more than 1,000 sets have been sold. If it is assumed that each volume is used once a month by only one of the engineers or scientists in an organization who would save 40 hours (at \$25 per hour) each time by obtaining and using the data and information from the TPRC Data Series, the total savings would be \$156,000,000 per year. Even if each volume is used only once a year by only one person, the total savings would be \$13,000,000 per year. If each volume is used by several persons, much larger savings to engineers and scientists would be achieved. Adding all the savings from all the major publications of TEPIAC over the years, one would realize how great a contribution TEPIAC has made.

TEPIAC has been maintaining a sound "Service Charge System" including an auditable detailed file of charges and users, and has been seeking its continual improvement. The nominal charges for TEPIAC products and services are as follows:

1. Bibliographic search. The nominal charge for a single bibliographic search is \$35. A single bibliographic search is defined as a search for a maximum of five properties of one material for any temperature range and subject area. In the cases of special search requirements, price quotations are given.



2. Technical consultation, data recommendation, data synthesis and prediction. Minor technical assistance are provided at the rate of \$25 per hour. Price quotations are given for extended technical services.
3. Publications. Brochures containing information on the content, availability, price, etc. are sent to requesters for information on major book and report publications. Copies of reprints of journal articles written by TEPIAC staff, if available, are sent to requesters free of charge.
4. Reproductions. The charge for microfiche reproduction is \$2.50 per fiche. Hard copy reproduction is charged at \$0.35 per page. A \$3.00 special handling charge will be added to the total charge for an order under \$10.00.
5. Promotional and current awareness products and general information on TEPIAC. These are provided at no cost.

Most routine users of scientific and technical information generally order and pay for TEPIAC's products and services through their local technical library or through their scientific and technical information office. TEPIAC has the following flexible payment options available:

1. Pre-paid account. This payment option allows an organization to deposit funds with TEPIAC/Purdue University. When TEPIAC delivers products or services in response to orders placed by organization's authorized employees, it will deduct the costs from the deposit account. The requester will be informed of the remaining dollar balance each time technical service is provided.
2. Telephone/letter authorization, pay later. A user may grant approval by telephone or letter for the performance of services for a specified nominal dollar value. TEPIAC provides the technical services to the requester, and Purdue University issues an invoice soon after, making reference to the purchase order number, if available, or to the authorization call or letter and the name of authorizing individual.
3. Standing order. This plan authorizes an organization to expend a specified amount of funds by anyone from the organization or by specified personnel only over a specified period. As products and

services are rendered, TEPIAC invoices the organization through Purdue University against this established standing order.

4. Blanket purchase agreement (BPA) or military deposit account. DOD agencies use this arrangement with a DD Form 1155 (order for supplies and services). A BPA according to the Armed Services Procurement Regulations (ASPR) is a "simplified method of filling anticipated repetitive needs for small quantities of supplies or services by establishing 'charge accounts' with qualified sources of supply. Blanket purchase agreements are designed to reduce administrative costs in accomplishing small purchases by eliminating the need for issuing individual purchase documents." In addition, BPA's allow for timely fulfillment of order.

It is interesting and informative to note those properties and materials on which information is most frequently requested by inquirers. Therefore, a study of the interest profile of all the technical inquiries in the 36-month period from 1 January 1977 to 31 December 1979 has been made and the findings are presented in Table 16. It can be observed from Table 16 that over 65% of the inquiries were on the top five of the 36 properties and top four of the material groups listed.

Since most users contacted TEPIAC for data and information via the telephone, TEPIAC has installed a national WATS line (No. 1-800-428-7675) to make it easier for all users to call TEPIAC toll free. TEPIAC has attempted a number of innovations in getting the word out and the WATS line is one of the contributions to establish a better and easier communication.

A list of organizations in the United States using TEPIAC inquiry services in the period 1 October 1975 to 31 December 1979 is given in Appendix 5.

TABLE 16. INTEREST PROFILE OF TECHNICAL INQUIRIES  
(For the Period 1 January 1977 to 31 December 1979)

A. Properties (listed in the order of interest)

1. Thermal Conductivity . . .	23.5%	14. Magnetic Susceptibility . . .	0.7%
2. Specific Heat . . . . .	15.2%	15. Absorption Coefficient . . .	0.7%
3. Thermal Linear Expansion .	14.1%	16. Thermoelectric Properties . .	0.7%
4. Electrical Resistivity . .	9.3%	17. Magnetic Hysteresis . . . . .	0.3%
5. Thermal Diffusivity . . .	6.8%	18. Mobility . . . . .	0.3%
6. Viscosity . . . . .	5.8%	19. Thermal Volumetric Expansion .	0.3%
7. Emittance . . . . .	4.2%	20. Energy Levels . . . . .	0.3%
8. Refractive Index . . . . .	4.2%	21. Thermal Contact Resistance . .	0.3%
9. Reflectance . . . . .	3.3%	22. Energy Bands . . . . .	0.2%
10. Absorptance . . . . .	3.0%	23. Energy Gap . . . . .	0.2%
11. Transmittance . . . . .	2.1%	24. Work Function . . . . .	0.1%
12. Dielectric Constant . . .	1.9%	25. Misc. (9 Electrical + 3 Thermo.)	1.7%
13. Dielectric Strength . . .	0.8%		

B. Materials (listed in the order of interest)

1. Inorganic Compounds . . .	26.1%	9. Minerals . . . . .	4.6%
2. Elements . . . . .	18.4%	10. Organic Compounds <sup>a</sup> . . . . .	3.4%
3. Non Ferrous Alloys . . . .	11.7%	11. Hydrocarbons . . . . .	1.3%
4. Ferrous Alloys . . . . .	9.4%	12. Solutions and Mixtures . . .	0.9%
5. Intermetallics . . . . .	6.0%	13. Foods . . . . .	0.8%
6. Composites and Systems . .	5.2%	14. Cermets . . . . .	0.5%
7. Polymers . . . . .	5.2%	15. Coatings . . . . .	0.4%
8. Glasses, Refractories, etc.	4.6%	16. Miscellaneous . . . . .	1.5%

<sup>a</sup> Excluding hydrocarbons.

## SECTION V

### CURRENT AWARENESS AND PROMOTION EFFORTS

The "Thermophysics and Electronics Newsletter" has been issued bimonthly since January 1972 to a circulation list of TEPIAC users and potential users as a means of keeping them abreast of significant developments and coming events, the availability of new information and publications, the initiation of new R&D programs, and of the availability of products and services from TEPIAC. The number of names in the mailing list has been increasing slowly and reached 11,000. In this 12-month period 6 issues of the Newsletter have been released with a total of 66,000 copies distributed.

The development of an enlarged and computerized mailing list for TEPIAC users and potential users has been accomplished. A simple profile code is given to each name on the mailing list so that the computer can generate selective mailing lists from a master file. The new mailing list therefore not only covers a greater percentage of TEPIAC's total audience, but also allows the isolation of selected portions of that audience for specialized mailings, which increases the effectiveness of the mailing and saves much money in dissemination costs.

In order to ensure that TEPIAC users and potential users are aware of the Center, the products and services it offers, and the benefits to be realized through use of the Center, promotional brochures and users guide are periodically issued and distributed, in addition to the distribution of the bimonthly Newsletter. Three new promotional brochures, two with 4 pages and the other with 2 pages, have been produced in this reporting period to make the users and potential users better acquainted with TEPIAC's functions, capabilities, technical assistance, products, and services.

In this 12-month period TEPIAC sponsored the Sixteenth International Thermal Conductivity Conference and the Seventh International Thermal Expansion Symposium, which were held at Chicago on November 7-9, 1979. Furthermore, TEPIAC staff participated in 14 other conferences and meetings. A list of these 16 conferences and meetings is given in Table 17.

TEPIAC has maintained periodic contacts with a number of national and international experts in the field of thermophysics and thermophysical and

TABLE 17. CONFERENCES AND MEETINGS PARTICIPATED IN BY TEPIAC STAFF MEMBERS  
IN THE PERIOD 1 JANUARY TO 31 DECEMBER 1979

<u>Name</u>	<u>Location</u>	<u>Date</u>
Seminar on "Minicomputer Data Base Management System"	Elmhurst, IL	Feb. 22, 1979
Carbon-Carbon Composites Data Bank Meeting	Dayton, OH	Feb. 23, 1979
ASTM Thermal Measurements Committee Meeting	Cincinnati, OH	March 22-23, 1979
Award Ceremony for an Award by Gould, Inc., with an Award Acceptance Speech on the History, Operation, Capabilities, Products, and Services of TEPIAC/CINDAS	Rolling Meadows, IL	April 20, 1979
Meeting on Carbon-Carbon Composites Data Bank	Dayton, OH	May 9-10, 1979
Symposium on Atomic Spectroscopy-1979	Tucson, AZ	Sept. 10-14, 1979
Meeting of ICSU-CODATA Task Group on Thermophysical Properties of Solids	Mol, Belgium	Sept. 24-25, 1979
Plenary Meeting for the Preparation of the 7th European Thermophysical Properties Conference	Mol, Belgium	Sept. 26, 1979
Eleventh Annual Symposium on Optical Materials for High Power Lasers	Boulder, CO	Oct. 30-31, 1979
High Power Laser Optical Components Conference	Boulder, CO	Nov. 1-2, 1979
Sixteenth International Thermal Conductivity Conference	Chicago, IL	Nov. 7-9, 1979
Seventh International Thermal Expansion Symposium	Chicago, IL	Nov. 7-9, 1979
Meeting of ASTM Committee on Thermal Diffusivity	Chicago, IL	Nov. 7, 1979
Carbon-Carbon Composites Data Bank TI/TD Meeting	Columbus, OH	Nov. 27-28, 1979
Carbon-Carbon Composites Data Bank Technical Meeting	Dayton, OH	Dec. 13, 1979
DOD Information Analysis Centers Directors/Managers Meeting	Alexandria, VA	Dec. 17, 1979

electronic properties and has developed cooperative working arrangements with a number of national and international laboratories and institutions engaged in thermophysical and/or electronic properties research for the exchange of ideas, technical information, and research results.

As part of the continuing effort to bring about improved awareness of the need and value of using evaluated reference data versus data directly taken from the literature and of the benefits to be realized through the use of Information Analysis Centers such as TEPIAC, a documentary film entitled "The Anatomy of Data" was produced. "The Anatomy of Data" points out and stresses the serious discord that exists among the data of science and technology as reported in the scientific and technical literature. Through on-location interviews with prominent scientists highly knowledgeable in this field, and using examples drawn from our files, the film illustrates the serious pitfalls an engineer or scientist may fall into unless he uses critically evaluated data prepared by such National Information Analysis Centers as TEPIAC. The role and usefulness of data synthesis is also stressed and demonstrated. This movie has been shown to about 184 organizations in this country and abroad.

On 20 April 1979 TEPIAC/CINDAS received an Award from Gould, Inc. at Gould Center, Rolling Meadows, Illinois for excellence in TEPIAC/CINDAS' performance. It is indeed rewarding to know that our efforts are so recognized as effective and worthwhile for such award from a leading corporation.

## SECTION VI

### OTHER PUBLICATIONS NOT UNDER THIS CONTRACT BUT IN DIRECT SUPPORT OF THIS PROGRAM

In the following are listed some selected technical products produced in this same period which are not under this contract but are in direct support of this program. Thus, CINDAS' other activities have benefited this program greatly.

1. "Absorption Coefficient of Alkali Halides (Part I)," Purdue University, CINDAS Report 54, 278 pp., 1979.
2. "Absorption Coefficient of Alkali Halides (Part II)," Purdue University, CINDAS Report 55, 148 pp., 1979.
3. "Data Analysis for Defense," National Defense, 63(354), 45-9, 1979.
4. "The Need of Science for Evaluated Information," Bulletin of the American Society for Information Science, 5(6), 44, 1979.
5. Masters Theses in the Pure and Applied Sciences Accepted by Colleges and Universities of the United States and Canada, Vol. 23, Plenum Press, New York, N.Y., 292 pp., 1979. This has been an annual publication of CINDAS with its first volume published in 1957. A brief statistical summary of coverage of this publication is given in Table 18. Table 19 shows a complete list of academic disciplines covered by the publication.

TABLE 18. STATISTICAL SUMMARY OF COVERAGE OF "MASTERS THESES IN THE PURE AND APPLIED SCIENCES"

<u>Volume No.</u>	<u>Publication Date</u>	<u>Thesis Year</u>	<u>No. of Pages</u>	<u>No. of Contributing Institutions</u>	<u>No. of Thesis Titles Reported</u>
1	Oct. 1957	1955	108	93	1,002
		1956		93	1,027
2	Aug. 1958	1957	104	154	1,727
3 <sup>a</sup>	Oct. 1959	1958	500	139	3,736
4	Dec. 1960	1959	443	162	4,984
5	Dec. 1961	1960	443	183	5,708
6	Aug. 1966	1961	127	186	5,911
7	Aug. 1966	1962	133	186	6,321
8	Aug. 1966	1963	143	175	6,505
9	Jan. 1968	1964	146	174	6,940
10	Jan. 1968	1965	156	170	7,310
11	Jan. 1968	1966	150	173	7,099
12	July 1968	1967	148	167	6,909
13	July 1969	1968	166	174	7,802
14	Jan. 1971	1969	151	175	7,160
15	July 1971	1970	153	183	7,413
16	July 1972	1971	152	182	7,170
17	July 1973	1972	179	250	8,513
18 <sup>b</sup>	Dec. 1974	1973	286	251	10,381
19	Dec. 1975	1974	285	229	10,045
20	Dec. 1976	1975	293	267	10,374
21	Nov. 1977	1976	290	244	10,586
22	Oct. 1978	1977	305	255	10,658
23	Nov. 1979	1978	292	247	10,432

<sup>a</sup> Volume 3 includes also doctoral dissertations for 1956-57 academic year, citing 2846 titles from 103 universities.

<sup>b</sup> Effective with Volume 18, the coverage has been extended to include Canadian universities.



TABLE 19. ACADEMIC DISCIPLINES COVERED BY THE "MASTERS THESES IN THE PURE AND APPLIED SCIENCES"<sup>a</sup>

1. Aerospace Engineering
2. Agricultural Economics, Sciences and Engineering
3. Architectural Engineering and Urban Planning
4. Astronomy
5. Astrophysics
6. Ceramic Engineering
7. Chemical Engineering
8. Chemistry and Biochemistry
9. Civil Engineering
10. Communications Engineering and Computer Science
11. Composite Engineering
12. Electrical Engineering
13. Engineering Mechanics
14. Engineering Physics
15. Engineering Science
16. Fuels, Combustion and Air Pollution
17. General and Environmental Engineering
18. Geochemistry and Soil Science
19. Geological Sciences and Geophysical Engineering
20. Geology
21. Geophysics
22. Industrial Engineering and Operations Research
23. Irrigation Engineering
24. Marine and Ocean Engineering
25. Materials Science and Engineering
26. Mechanical Engineering and Bioengineering
27. Metallurgy
28. Meteorology and Atmospheric Sciences
29. Mineralogy and Petrology
30. Mining and Metallurgical Engineering
31. Missile and Space Systems Engineering
32. Nuclear Engineering
33. Nuclear Physics
34. Nuclear Science
35. Oceanography and Marine Science
36. Petroleum and Natural Gas Engineering
37. Photogrammetric and Geodetic Engineering
38. Physics and Biophysics
39. Plastics Engineering
40. Wood Technology, Forestry and Forest Science
41. Reactor Science
42. Sanitary Engineering and Water Pollution and Resources
43. Textile Technology
44. Transportation Engineering

---

<sup>a</sup> Mathematical and most life sciences have been excluded on a purely arbitrary basis simply to limit the scope of the work.

## SECTION VII

### CONCLUSIONS AND FUTURE PLANNING

This Annual Final Report has covered all the tasks and activities of the Thermophysical and Electronic Properties Information Analysis Center in the 12-month reporting period 1 January to 31 December 1979 and has contained details of all technical work accomplished and information gained in the performance of the contract.

TEPIAC has been maintaining a comprehensive, authoritative, and up-to-date national data base on thermophysical, electronic, electrical, magnetic, and optical properties of all important materials, and has been disseminating the resulting data and information to the entire DOD community and general TEPIAC users at large through the publication of major reference works on property data and information and of other technical products and at the same time has been providing the much needed data and information directly to individual users through technical and bibliographic inquiry and authoritative information and data analysis services. As the objective of TEPIAC operations is to increase the productivity of scientists, engineers, and technicians engaged in scientific and engineering programs for the Department of Defense by maintaining a comprehensive and up-to-date national data base for use by the entire DOD community and by providing authoritative information and data analysis services, it is obvious that the objective of TEPIAC operations has been achieved most successfully. In fact, the accomplishments of TEPIAC have far exceeded the requirements of the contract. Under CINDAS' operation, TEPIAC has long achieved the full operational status of a Full-Service DOD Information Analysis Center. TEPIAC has been well oriented to the needs of its user community, and its products and services are well-known nationally and, indeed, internationally.

As CINDAS operates through the multiple sponsorship of organizations having a common interest in property data and information, the results obtained from the support provided by one group benefits all others. Therefore, the supports from all other sources have benefited this contract greatly. Since the supports from other sources have been approximately equal to that from DLA, TEPIAC/CINDAS has been returning to DLA the results of two dollars of research for every dollar invested by the DLA. Thus TEPIAC has met its additional goal of achieving an annual rate of income from its products, services,

and other financial supports equal to at least 50% of the initial DLA annual funding of this contract.

Due to the disturbing fact that the existing data and information on material properties recorded in the scientific and technical literature are often conflicting, widely diverging, and subject to large uncertainty, TEPIAC has traditionally stressed data evaluation, analysis, and synthesis, and the generation of evaluated reference data, even though TEPIAC is a full-service Information Analysis Center. As a result, TEPIAC can provide to its users not only just any or all available data and information, but also the evaluated correct data and information, and furthermore in many cases TEPIAC can also provide predicted data and information to the users even when the needed data and information are completely lacking and nonexistent.

In future years TEPIAC will continue to be operated as a full-service DOD Information Analysis Center using the methods and procedures developed and fully established at CINDAS over the years for the most efficient and effective service to the Department of Defense and its scientific and technical community. The past successful performance of TEPIAC assures continued future success in achieving its objective and goal and accomplishing all its tasks.

Among the tasks of TEPIAC, the preparation and publication of volumes in the new CINDAS Data Series on Material Properties is one that should gain much greater momentum, as TEPIAC/CINDAS has always felt that the maximum optimization of its efforts in serving the end-user of data and information can best be realized through the publication of major reference works. Due to the low funding level of this program, the level of effort that can be devoted to this most important task is believed far too low. It is earnestly hoped that the level of effort for the data book preparation can be increased so that more volumes of the new CINDAS Data Series can be produced in a timely manner.

In addition to our Data Series, it is appropriate at this time to also review briefly some of the new major products we anticipate to complete during 1980; these are:

1. Publication of a new six-volume "Retrieval Guide to Thermophysical Properties Research Literature" which would merge together the present Basic Edition, Supplement I, and Supplement II. This would create a most convenient reference work for users.

2. Preparation of bibliographic computer tapes, for lease or license, representing TEPIAC's new retrieval system to be referred to as the Thermophysical and Electronic Properties Information System (TEPIS).
3. Development of an interactive numerical data base of evaluated numerical data on thermophysical and electronic properties.

These above major products were in the development stage for sometime under multiple support, however, the low level of funding has required a longer period of time than originally anticipated.

APPENDICES

APPENDIX 1. TABLE OF CONTENTS OF THE FOUR COMPLETED VOLUMES OF THE  
"McGRAW-HILL/CINDAS DATA SERIES ON MATERIAL PROPERTIES"

VOLUME II-1. THERMAL ACCOMMODATION AND ADSORPTION COEFFICIENTS OF GASES

	<u>Page</u>
PREFACE . . . . .	111
INTRODUCTION TO THERMAL ACCOMMODATION AND ADSORPTION COEFFICIENTS . . . . .	v
NOMENCLATURE . . . . .	x111
NOMENCLATURE TO CHAPTERS I AND II . . . . .	x111
NOMENCLATURE TO CHAPTER III . . . . .	xx111
NOMENCLATURE TO CHAPTER IV . . . . .	xxx1
NOMENCLATURE TO CHAPTER VI . . . . .	xxxv
CHAPTER I. INTRODUCTION AND REVIEW OF THERMAL ACCOMMODATION COEFFICIENT . . . . .	3
INTRODUCTION . . . . .	3
EARLIER REVIEWS . . . . .	9
CHAPTER II. THEORIES OF HEAT TRANSFER IN A GAS-SOLID SYSTEM IN THE DETERMINATION OF THERMAL ACCOMMODATION COEFFICIENT . . . . .	15
THE LOW PRESSURE METHOD . . . . .	15
THE TEMPERATURE-JUMP METHOD . . . . .	22
THE CONSTANT-POWER METHOD . . . . .	27
OTHER METHODS APPLICABLE OVER A WIDER PRESSURE RANGE . . . . .	34
The Boltzmann Equation . . . . .	36
The Bhatnagar-Gross-Krook (BGK) Model . . . . .	38
The Gross-Jackson Generalization of the BGK-Model . . . . .	38
Application of BGK-Model to Parallel Plates . . . . .	39
Application of BGK-Model to Concentric Cylinders . . . . .	42
Maxwell's Equation for Transfer of Macroscopic Quantities . . . . .	46
The Thirteen Moment Method of Grad . . . . .	47
The Four Moment Method of Lees and Liu - Parallel Plate Apparatus . . . . .	48
The Four Moment Method of Lees and Liu - Concentric Cylinder Apparatus . . . . .	50
Generalization of the Four Moment Method for the Case of Arbitrary Accommodation . . . . .	55
Iteration Methods for the Near Free-Molecule-Flow Regime . . . . .	58
CHAPTER III. METHODS OF MEASUREMENT OF THE THERMAL ACCOMMODATION COEFFICIENT . . . . .	61
INTRODUCTION . . . . .	61
THE PARALLEL PLATE METHOD . . . . .	62
Introduction . . . . .	62

	<u>Page</u>
Theory of Heat Transfer . . . . .	64
Free-Molecule-Flow Regime . . . . .	64
Temperature-Jump Regime . . . . .	65
Transition Regime . . . . .	67
Experimental Techniques . . . . .	68
THE COAXIAL CYLINDER METHOD . . . . .	70
Introduction . . . . .	70
Theory of Heat Transfer . . . . .	72
Experimental Techniques . . . . .	76
THE CONCENTRIC TUBE METHOD . . . . .	94
THE HOT BAND METHOD . . . . .	96
THE GUARDED CALORIMETER METHOD . . . . .	97
THE HOT WIRE-BAND METHOD . . . . .	101
THE LIGHT BEAM METHOD . . . . .	103
THE MOLECULAR BEAM DIRECT ENERGY MEASUREMENT METHOD . . . . .	104
THE MOLECULAR BEAM TIME-OF-FLIGHT MEASUREMENT METHOD . . . . .	105
OTHER MOLECULAR BEAM METHODS . . . . .	110
THE SPECTROSCOPIC EQUILIBRIUM METHOD . . . . .	115
THE SPECTROSCOPIC NON-EQUILIBRIUM METHOD . . . . .	123
THE SHOCK TUBE METHOD . . . . .	125
THE HETEROGENEOUS NUCLEATION METHOD . . . . .	130
 CHAPTER IV. CALCULATION AND PREDICTION OF THERMAL ACCOMMODATION COEFFICIENT . . . . .	 133
INTRODUCTION . . . . .	133
THEORETICAL FORMULAS . . . . .	134
SEMI-EMPIRICAL FORMULAS . . . . .	142
 CHAPTER V. THERMAL ACCOMMODATION COEFFICIENT DATA . . . . .	 147
PRESENTATION OF DATA . . . . .	147
Procedure for Recording the Experimental Details . . . . .	147
Interpretation of Key Parameters and Their Effect on the Data . . . . .	147
Scope of Coverage - A Statistical Summary . . . . .	150
NUMERICAL DATA ON THERMAL ACCOMMODATION COEFFICIENTS . . . . .	153
 CHAPTER VI. ADSORPTION OF GASES ON SOLIDS . . . . .	 309
A REVIEW OF THEORY AND DATA . . . . .	309
Introduction . . . . .	309
Theories of Adsorption . . . . .	310
EXPERIMENTAL RESULTS . . . . .	316
 REFERENCES . . . . .	 375
REFERENCES TO THERMAL ACCOMMODATION COEFFICIENT . . . . .	375
References to Text: Chapters I through IV . . . . .	375
References to Data: Chapter V . . . . .	391
REFERENCES TO GAS ADSORPTION: Chapter VI . . . . .	396

	<u>Page</u>
INDEX TO SYSTEMS FOR THERMAL ACCOMMODATION COEFFICIENT (Chapter V) . . . . .	403
INDEX TO SYSTEMS FOR ADSORPTION OF CASES (Chapter VI) . . . . .	407
SUBJECT INDEX . . . . .	409



# VOLUME II-2. PHYSICAL PROPERTIES OF ROCKS AND MINERALS

## TABLE OF CONTENTS

FOREWORD -----	<u>Page</u> ix
PREFACE TO THE SERIES -----	xi
INTRODUCTION -----	xiii
CHAPTER 1 - CONSTITUTION OF ROCKS	
1.1. INTRODUCTION -----	1
1.2. ROCK MATERIAL AND ROCK MASS -----	2
1.3. ROCK AND SOIL -----	3
1.4. GEOCHEMISTRY -----	5
1.5. MINERALOGY -----	7
1.6. ROCK FABRICS -----	10
1.7. GEOLOGIC CLASSIFICATION OF ROCKS -----	11
1.8. ENGINEERING CLASSIFICATION OF ROCKS -----	15
1.9. COMPARISON TO OTHER MATERIALS -----	17
1.10. SUMMARY -----	18
REFERENCES -----	18
CHAPTER 2 - PARAMETRIC CONSIDERATIONS	
2.1. INTRODUCTION -----	21
2.2. SAMPLING CONSIDERATIONS -----	21
2.3. GEOCHEMICAL CONSIDERATIONS -----	23
2.4. TEXTURAL CONSIDERATIONS -----	24
2.5. ENVIRONMENTAL CONSIDERATIONS -----	25
2.6. MEASUREMENT CONSIDERATIONS -----	25
2.7. SUMMARY -----	26
BIBLIOGRAPHY -----	27
CHAPTER 3 - DENSITY	
3.0. NOMENCLATURE -----	29
3.1. INTRODUCTION -----	29
3.2. DEFINITION OF TERMS -----	29

3.3.	LABORATORY METHODS -----	30
3.4.	FIELD METHODS -----	31
3.5.	STATISTICAL ANALYSIS OF PUBLISHED DATA -----	33
3.6.	CORRELATION POSSIBILITIES -----	36
3.7.	SUMMARY -----	37
	REFERENCES -----	37
	APPENDIX - BIBLIOGRAPHY FOR DATA IN TABLE 3.2 -----	39

#### CHAPTER 4 - POROSITY, PERMEABILITY, DISTRIBUTION COEFFICIENTS, AND DISPERSIVITY

4.0.	NOMENCLATURE -----	45
4.1.	INTRODUCTION AND SCOPE -----	46
4.2.	POROSITY -----	46
4.2.1.	GENERAL DEFINITIONS -----	46
4.2.2.	HISTORICAL ASPECTS -----	47
4.3.	PERMEABILITY -----	48
4.3.1.	GENERAL DEFINITIONS -----	48
4.3.2.	HISTORICAL ASPECTS -----	48
4.3.3.	DISCUSSION -----	49
4.4.	DISTRIBUTION COEFFICIENTS -----	49
4.4.1.	GENERAL COMMENTS -----	49
4.4.2.	HISTORICAL ASPECTS -----	50
4.4.3.	GENERAL DEFINITION AND DISCUSSION -----	50
4.5.	DISPERSIVITY -----	51
4.5.1.	GENERAL DEFINITIONS -----	51
4.5.2.	DISCUSSION -----	52
4.6.	SUMMARY -----	52
	REFERENCES -----	78

#### CHAPTER 5 - STRENGTH OF ROCK

5.0.	NOMENCLATURE -----	83
5.1.	INTRODUCTION -----	84
5.1.1.	DEFINITIONS -----	84
5.1.2.	ROCK MASS STRENGTH -----	85
5.2.	UNIAXIAL COMPRESSIVE STRENGTH -----	85
5.2.1.	END EFFECTS -----	85
5.2.2.	SIZE -----	88
5.2.3.	RATE OF LOADING -----	89
5.2.4.	EFFECT OF MOISTURE -----	89
5.2.5.	GRAIN SIZE -----	89
5.2.6.	MACHINE STIFFNESS -----	89
5.2.7.	POINT-LOAD TEST -----	90
5.2.8.	COMPRESSIVE STRENGTH DETERMINATION USING IRREGULAR SPECIMENS -----	90

5.3.	CONFINED COMPRESSIVE STRENGTH -----	91
5.3.1.	CONFINING PRESSURE -----	91
5.3.2.	PORE PRESSURE -----	91
5.3.3.	VOLUME CHANGES -----	92
5.3.4.	TEMPERATURE -----	94
5.3.5.	BRITTLE-DUCTILE TRANSITION -----	95
5.4.	TENSILE STRENGTH -----	95
5.4.1.	DIRECT PULL TEST -----	97
5.4.2.	SPLITTING TENSILE STRENGTH -----	98
5.4.3.	RING-LOAD TEST -----	99
5.4.4.	HOOP-STRESS METHOD -----	100
5.4.5.	MODULUS OF RUPTURE -----	100
5.4.6.	PUNCH TEST -----	100
5.5.	SHEAR STRENGTH -----	101
5.5.1.	SHEAR ALONG A PLANE -----	101
5.5.2.	SHEAR THROUGH THE ROCK SUBSTANCE -----	101
5.6.	ROCK FAILURE -----	103
5.6.1.	CLASSICAL THEORIES -----	103
5.6.2.	NAVIER-COULOMB THEORY -----	103
5.6.3.	MOHR HYPOTHESIS -----	103
5.6.4.	GRIFFITH CRACK THEORY -----	105
5.7.	ROCK FATIGUE -----	105
5.8.	CREEP -----	108
5.8.1.	CREEP RELATIONS -----	111
5.8.2.	RELATIONSHIPS BETWEEN STRESS AND CREEP RATE -----	112
5.8.3.	EFFECT OF TEMPERATURE -----	114
5.8.4.	PHENOMENOLOGICAL MODELS -----	114
5.9.	SUMMARY -----	114
	REFERENCES -----	117
	APPENDIX - REFERENCES TO DATA IN TABLES 5.1, 5.2, AND 5.3 -----	120

#### CHAPTER 6 - STATIC STRESS-STRAIN RELATIONSHIP

6.0.	NOMENCLATURE -----	123
6.1.	INTRODUCTION -----	124
6.2.	DEFINITIONS -----	124
6.3.	MINERAL CONTENT, MICROFRACTURES, AND ANISOTROPY -----	126
6.4.	METHODS OF MEASUREMENT -----	127
6.4.1.	UNIAXIAL LOADING -----	127
6.4.2.	TRIAXIAL LOADING -----	129
6.4.3.	CYCLIC LOADING -----	130
6.4.4.	HYDROSTATIC LOADING -----	130

6.5.	LABORATORY TEST RESULTS -----	131
6.5.1.	LABORATORY TESTS - UNIAXIAL STRESS LOADING -----	131
6.5.2.	LABORATORY TESTS - UNIAXIAL STRAIN LOADING -----	141
6.5.3.	CYCLIC LOADING -----	150
6.5.4.	LABORATORY TESTS - HYDROSTATIC LOADING -----	152
6.5.5.	LABORATORY TESTS AT ELEVATED TEMPERATURES -----	165
6.6.	FIELD TEST RESULTS -----	169
6.6.1.	PLATE JACKING TEST -----	169
6.6.2.	SLOT-AND-FLAT-JACK METHOD -----	171
6.6.3.	BOREHOLE JACKING TEST -----	172
6.7.	SUMMARY -----	173
	REFERENCES -----	174

#### CHAPTER 7 - SHEAR RESISTANCE AND DEFORMABILITY OF ROCK DISCONTINUITIES

7.0.	NOMENCLATURE -----	177
7.1.	INTRODUCTION, TERMINOLOGY, AND PERSPECTIVE -----	178
7.1.1.	INTRODUCTION -----	178
7.1.2.	TERMINOLOGY -----	178
7.1.3.	PERSPECTIVE -----	179
7.2.	THEORIES FOR DISCONTINUITY BEHAVIOR -----	181
7.2.1.	INTRODUCTION -----	181
7.2.2.	MODELS OF DISCONTINUITY RESISTANCE -----	181
	7.2.2.1. Mechanistic -----	181
	7.2.2.2. Curve Descriptions -----	184
7.2.3.	MODELS OF DISCONTINUITY DEFORMABILITY -----	186
7.3.	EQUIPMENT AND METHODOLOGIES FOR SHEARING DISCONTINUITIES -----	189
7.3.1.	INTRODUCTION -----	189
7.3.2.	EQUIPMENT -----	189
	7.3.2.1. Triaxial Compression -----	189
	7.3.2.2. Direct Shearing -----	190
	7.3.2.3. Discontinuity Profiling and Wall Rock Testing -----	194
7.3.3.	EXAMPLE METHODOLOGIES -----	194
7.3.4.	CONCLUSIONS -----	198
7.4.	DISCONTINUITY RESISTANCE AND DEFORMABILITY -----	198
7.4.1.	INTRODUCTION -----	198
7.4.2.	PRESENTATION OF RESISTANCE DATA -----	198
	7.4.2.1. Effects of Water -----	206
	7.4.2.2. Importance of Mineralogy and Discontinuity Type -----	207
	7.4.2.3. Variation of Resistance with Normal Stress -----	207
7.4.3.	PRESENTATION OF DEFORMABILITY DATA -----	211
	7.4.3.1. Variation of Shear Stiffness -----	211
	7.4.3.2. Variation of Normal Stiffness -----	215
7.5.	SUMMARY -----	215
	REFERENCES -----	217

## CHAPTER 8 - SEISMIC WAVE VELOCITY

8.0.	NOMENCLATURE -----	221
8.1.	INTRODUCTION -----	222
8.2.	EXPERIMENTAL METHODS -----	222
8.3.	RELATION BETWEEN VELOCITY AND ELASTIC PROPERTIES -----	223
8.4.	PARAMETRIC EFFECTS -----	225
8.5.	DATA PRESENTATION -----	226
8.6.	DISCUSSION OF DATA -----	230
8.7.	SUMMARY -----	253
	REFERENCES -----	254

## CHAPTER 9 - ELECTRICAL PROPERTIES OF ROCKS

9.0.	NOMENCLATURE -----	257
9.1.	INTRODUCTION -----	258
9.2.	PARAMETERS IN ELECTRICAL QUANTITIES -----	259
9.3.	MECHANISMS AND PROCESSES OF CHARGE TRANSPORT -----	261
9.4.	ELECTRICAL CONDUCTIVITY - CHARGE TRANSPORT -----	264
9.5.	ELECTRICAL CONDUCTIVITY OF MINERALS AND ROCKS -----	265
9.6.	ELECTRICAL PROPERTIES OF WATER AND AQUEOUS SOLUTIONS -----	266
9.7.	WATER IN ROCKS - MIXING LAWS -----	272
9.8.	SUMMARY -----	286
	REFERENCES AND BIBLIOGRAPHY -----	287
	APPENDICES -----	298
	APPENDIX A - TABLES OF ROOM TEMPERATURE ELECTRICAL PROPERTIES FOR SELECTED ROCKS, MINERALS AND CHEMICAL COMPOUNDS AND DIELECTRIC PERMITTIVITY STATISTICS [Olhoeft, 1979e] -----	298
	APPENDIX B - ELECTRICAL CONDUCTIVITY OF ROCKS AND MINERALS -----	325

## CHAPTER 10 - MAGNETIC PROPERTIES OF ROCKS AND MINERALS

10.0.	NOMENCLATURE -----	331
10.1.	INTRODUCTION -----	331
10.2.	DIAMAGNETISM -----	332
10.3.	PARAMAGNETISM -----	333
10.4.	FERROMAGNETISM -----	335
10.5.	HYSTERESIS -----	335
10.6.	ANTIFERROMAGNETISM -----	336
10.7.	WEAK FERROMAGNETISM -----	338
10.8.	FERRIMAGNETISM -----	339
10.9.	MAGNETITE - ULVOSPINEL SERIES -----	340
10.10.	HEMATITE - ILMENITE SERIES -----	341
10.11.	ALTERATION -----	342
10.12.	IRON OXYHYDROXIDES -----	345

10.13.	IRON-NICKEL-COBALT -----	346
10.14.	SUPERPARAMAGNETIC (SP) - SINGLE DOMAIN (SD) IRON -----	347
10.15.	SEDIMENTS -----	352
10.16.	OCEAN BASALTS -----	352
10.17.	CONTINENTAL ROCKS -----	353
	10.17.1. ACID EXTRUSIVES -----	353
	10.17.2. BASIC EXTRUSIVES -----	354
	10.17.3. ACID INTRUSIVES -----	356
	10.17.4. IRON FORMATIONS -----	356
10.18.	SUMMARY -----	357
	REFERENCES -----	358

#### CHAPTER 11 - MELTING CURVES OF ROCKS AND VISCOSITY OF ROCK-FORMING MELTS

11.1.	INTRODUCTION -----	361
11.2.	EXPERIMENTAL TECHNIQUE ON MELTING CURVE MEASUREMENT -----	363
11.3.	MELTING INTERVALS -----	363
11.4.	ROLE OF VOLATILES IN SILICATE MELTS -----	369
11.5.	MULTICOMPONENT VOLATILE SYSTEMS -----	371
11.6.	EXPERIMENTAL RESULTS ON MELTING AND CRYSTALLIZATION TEMPERATURES OF ROCKS -----	372
11.7.	DATA -----	373
11.8.	MELTING RELATIONS AT PRESSURES ABOVE ONE ATMOSPHERE -----	383
11.9.	MELTING IN THE PRESENCE OF VOLATILES -----	388
11.10.	VISCOSITY AND DENSITY OF MELTS -----	394
11.11.	EXPERIMENTAL TECHNIQUES ON VISCOSITY MEASUREMENT -----	396
11.12.	VISCOSITY DATA -----	397
11.13.	DENSITY OF SILICATE MELTS -----	400
11.14.	SUMMARY -----	400
	REFERENCES -----	402
	APPENDIX - DEFINITIONS -----	406

#### CHAPTER 12 - THERMOPHYSICAL PROPERTIES OF ROCKS

12.0.	NOMENCLATURE -----	409
12.1.	INTRODUCTION -----	410
12.2.	DEFINITIONS AND THEORETICAL CONSIDERATIONS -----	411
	12.2.1. CONVECTIVE HEAT TRANSFER -----	411
	12.2.2. RADIATIVE HEAT TRANSFER -----	411
	12.2.3. PHONON CONDUCTION -----	411
	12.2.4. FACTORS WHICH INFLUENCE THERMAL CONDUCTIVITY -----	413
	12.2.5. COEFFICIENT OF LINEAR THERMAL EXPANSION -----	413
	12.2.6. THERMAL CAPACITY -----	413
	12.2.7. THERMAL DIFFUSIVITY -----	413

12.3.	MEASUREMENT METHODS FOR THERMAL CONDUCTIVITY -----	414
12.3.1.	DIVIDED BAR TECHNIQUE -----	415
12.3.2.	STACKED DISKS -----	415
12.3.3.	CYLINDRICAL HEAT FLOW TECHNIQUE -----	415
12.4.	DISCUSSION OF SOURCES OF ERROR -----	416
12.4.1.	SAMPLING ERRORS -----	416
12.4.2.	CONTACT RESISTANCE ERROR -----	417
12.5.	METHODS FOR THE ESTIMATION OF THERMAL CONDUCTIVITY -----	417
12.6.	COMBINATIONAL METHODS -----	420
12.7.	MEASUREMENT METHODS FOR THERMAL EXPANSION -----	420
12.7.1.	PUSH-ROD DILATOMETERS -----	420
12.7.2.	INTERFEROMETERS -----	421
12.7.3.	X-RAY METHODS -----	423
12.8.	SUMMARY -----	424
	REFERENCES -----	425
	APPENDIX - NUMERICAL DATA -----	427
	INTRODUCTORY REMARKS -----	427
	INDEX TO BIBLIOGRAPHY TO DATA ON SELECTED ROCKS AND PROPERTIES -----	484
	BIBLIOGRAPHY TO DATA ON SELECTED ROCKS AND PROPERTIES -----	489

#### CHAPTER 13 - HEAT FLOW FROM THE CRUST OF THE UNITED STATES

13.1.	INTRODUCTION -----	503
13.1.1.	TERMINOLOGY AND CONVENTIONS -----	503
13.1.2.	TECHNIQUES OF MEASUREMENT -----	503
13.2.	SCALE AND DEPTH OF HEAT-FLOW STUDIES -----	504
13.2.1.	REGIONAL THERMAL REGIMES -----	504
13.2.2.	LOCAL STUDIES RELATED TO GEOTHERMAL ENERGY -----	505
13.3.	HEAT FLOW AND NEAR-SURFACE RADIOACTIVITY -----	505
13.3.1.	STATUS OF OBSERVATIONS -----	505
13.3.2.	THE CONCEPT OF REDUCED HEAT FLOW AND ITS EMPIRICAL BASIS -----	506
13.3.3.	HEAT-FLOW PROVINCES -----	506
13.4.	HEAT FLOW AND CONVECTIVE PROCESSES -----	507
13.5.	HEAT-FLOW MAP OF THE CONTERMINOUS UNITED STATES AND ADJOINING REGIONS OF CANADA AND MEXICO -----	510
13.6.	REGIONAL HEAT-FLOW MAPS -----	510
13.7.	HEAT FLOW IN THE PACIFIC NORTHWEST -----	510
13.7.1.	INTRODUCTION -----	510
13.7.2.	COAST RANGES--WILLAMETTE VALLEY, PUGET LOWLAND--KLAMATH MOUNTAINS--WESTERN CASCADE RANGE -----	516
13.7.3.	GREAT PLAINS -----	516
13.7.4.	MIDDLE ROCKY MOUNTAINS -----	516
13.7.5.	NORTHERN ROCKY MOUNTAINS--BLUE MOUNTAINS -----	518
13.7.6.	COLUMBIA BASIN -----	518
13.7.7.	SOUTHERN IDAHO BATHOLITH -----	518

13.7.8.	YOUNG VOLCANIC AND TECTONIC PROVINCES -----	519
13.7.9.	OREGON HIGH CASCADE RANGE--WASHINGTON CASCADE RANGE -----	519
13.7.10.	BASIN AND RANGE PROVINCE -----	520
13.7.11.	OREGON HIGH LAVA PLAINS -----	520
13.7.12.	OXYHEE UPLAND -----	520
13.7.13.	WESTERN SNAKE RIVER PLAIN -----	520
13.7.14.	EASTERN SNAKE RIVER PLAIN -----	521
13.7.15.	ISLAND PARK--YELLOWSTONE NATIONAL PARK -----	521
13.7.16.	ORIGINS OF HEAT-FLOW PATTERNS -----	521
13.8.	HEAT FLOW IN NORTHERN AND CENTRAL CALIFORNIA -----	522
13.8.1.	INTRODUCTION -----	522
13.8.2.	KLAMATH MOUNTAINS -----	522
13.8.3.	CALIFORNIA COAST RANGES -----	522
13.8.4.	GREAT CENTRAL VALLEY -----	524
13.8.5.	SIERRA NEVADA -----	524
13.9.	HEAT FLOW IN SOUTHERN CALIFORNIA, SOUTHERN NEVADA, AND ARIZONA -----	524
13.9.1.	INTRODUCTION -----	524
13.9.2.	TRANSVERSE RANGES -----	524
13.9.3.	THE MOJAVE BLOCK -----	525
13.9.4.	SOUTHERN CALIFORNIA BATHOLITH -----	525
13.9.5.	SOUTHERN BASIN AND RANGE PROVINCE -----	526
13.9.6.	COLORADO PLATEAU -----	526
13.10.	HEAT FLOW AND GENERALIZED GEOLOGY IN EASTERN ARIZONA, THE RIO GRANDE RIFT, THE SOUTHERN ROCKY MOUNTAINS, AND THE NORTHERN AND CENTRAL ROCKY MOUNTAINS -----	526
13.10.1.	INTRODUCTION -----	526
13.10.2.	THE SOUTHERN ROCKY MOUNTAINS -----	529
13.10.3.	THE WESTERN GREAT PLAINS -----	529
13.10.4.	THE EASTERN COLORADO PLATEAU -----	530
13.10.5.	THE SOUTHEASTERN BASIN AND RANGE PROVINCE -----	530
13.10.6.	THE WYOMING BASIN -----	530
13.10.7.	MIDDLE ROCKY MOUNTAINS AND WESTERN GREAT PLAINS IN WYOMING -----	530
13.10.8.	YELLOWSTONE PARK-ABSAROKA MOUNTAIN REGION -----	531
13.10.9.	THE NORTHERN ROCKY MOUNTAINS -----	531
13.11.	HEAT FLOW AND THE MAJOR TECTONIC UNITS OF UTAH -----	531
13.12.	HEAT FLOW AND GENERALIZED GEOLOGY IN THE SOUTHEASTERN UNITED STATES -----	533
13.13.	HEAT FLOW AND GENERALIZED GEOLOGY IN THE NORTHEASTERN UNITED STATES -----	536
13.14.	HEAT FLOW IN ALASKA -----	539
13.15.	HEAT-FLOW MAP OF THE UNITED STATES BASED ON SILICA GEOTHERMOMETRY -----	540
13.15.1.	INTRODUCTION -----	540
13.15.2.	PREPARATION OF FIGURE 13.18 -----	542
13.15.3.	INTERPRETATION -----	543
13.16.	SUMMARY -----	544
	REFERENCES -----	545



# VOLUME III-1. PROPERTIES OF SELECTED FERROUS ALLOYING ELEMENTS

## CONTENTS

	<u>Page</u>
FOREWORD . . . . .	vii
PREFACE TO THE SERIES . . . . .	ix
INTRODUCTION . . . . .	xi
CHAPTER 1. GENERAL BACKGROUND . . . . .	1
1.1. Presentation of Data . . . . .	1
1.2. Data Evaluation and Generation of Recommended Values . . . . .	2
1.3. Symbols and Abbreviations . . . . .	3
1.4. Conversion Factors . . . . .	6
CHAPTER 2. CHROMIUM . . . . .	9
2.1. Physical Constants and Room-Temperature Mechanical Properties . . . . .	9
2.2. Thermal Conductivity . . . . .	10
2.3. Specific Heat . . . . .	14
2.4. Thermal Linear Expansion . . . . .	17
2.5. Thermal Diffusivity . . . . .	21
2.6. Thermal Emittance . . . . .	23
2.7. Thermal Reflectance . . . . .	28
2.8. Thermal Absorptance and Transmittance . . . . .	30
2.9. Viscosity . . . . .	31
2.10. Electrical Resistivity . . . . .	32
2.11. Thermoelectric Power . . . . .	37
2.12. Hall Coefficient . . . . .	40
2.13. Optical Constants . . . . .	44
2.14. Magnetic Susceptibility . . . . .	49
CHAPTER 3. COBALT . . . . .	53
3.1. Physical Constants and Room-Temperature Mechanical Properties . . . . .	53
3.2. Thermal Conductivity . . . . .	54
3.3. Specific Heat . . . . .	58
3.4. Thermal Linear Expansion . . . . .	61
3.5. Thermal Diffusivity . . . . .	66
3.6. Thermal Emittance . . . . .	68
3.7. Thermal Reflectance . . . . .	72
3.8. Thermal Absorptance and Solar Absorptance to Emittance Ratio . . . . .	74
3.9. Viscosity . . . . .	74
3.10. Electrical Resistivity . . . . .	76
3.11. Thermoelectric Power . . . . .	81
3.12. Hall Coefficient . . . . .	83
3.13. Optical Constants . . . . .	87
3.14. Magnetic Susceptibility . . . . .	91

AD-A083 943

CENTER FOR INFORMATION AND NUMERICAL DATA ANALYSIS AN--ETC F/G 5/2  
THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS C--ETC(U)  
MAR 80 C HO DLA900-79-C-1007

UNCLASSIFIED

AMMRC-TR-80-15

NL

2 OF 2  
NO  
ADP 3/41.2

END

DATE

FILED

DTIC

	<u>Page</u>
CHAPTER 4. IRON . . . . .	95
4.1. Physical Constants and Room-Temperature Mechanical Properties . . . . .	95
4.2. Thermal Conductivity . . . . .	96
4.3. Specific Heat . . . . .	102
4.4. Thermal Linear Expansion . . . . .	106
4.5. Thermal Diffusivity . . . . .	110
4.6. Thermal Emittance . . . . .	113
4.7. Thermal Reflectance . . . . .	120
4.8. Thermal Absorptance . . . . .	123
4.9. Viscosity . . . . .	123
4.10. Electrical Resistivity . . . . .	126
4.11. Thermoelectric Power . . . . .	131
4.12. Hall Coefficient . . . . .	135
4.13. Optical Constants . . . . .	141
4.14. Magnetic Susceptibility . . . . .	145
CHAPTER 5. MANGANESE . . . . .	149
5.1. Physical Constants and Room-Temperature Mechanical Properties . . . . .	149
5.2. Thermal Conductivity . . . . .	151
5.3. Specific Heat . . . . .	153
5.4. Thermal Linear Expansion . . . . .	156
5.5. Thermal Diffusivity . . . . .	159
5.6. Thermal Emittance . . . . .	161
5.7. Thermal Reflectance . . . . .	163
5.8. Thermal Absorptance . . . . .	165
5.9. Viscosity . . . . .	165
5.10. Electrical Resistivity . . . . .	167
5.11. Thermoelectric Power . . . . .	170
5.12. Hall Coefficient . . . . .	172
5.13. Optical Constants . . . . .	174
5.14. Magnetic Susceptibility . . . . .	179
CHAPTER 6. NICKEL . . . . .	183
6.1. Physical Constants and Room-Temperature Mechanical Properties . . . . .	183
6.2. Thermal Conductivity . . . . .	184
6.3. Specific Heat . . . . .	189
6.4. Thermal Linear Expansion . . . . .	192
6.5. Thermal Diffusivity . . . . .	196
6.6. Thermal Emittance . . . . .	198
6.7. Thermal Reflectance . . . . .	204
6.8. Thermal Absorptance and Solar Absorptance to Emittance Ratio . . . . .	207
6.9. Viscosity . . . . .	208
6.10. Electrical Resistivity . . . . .	209
6.11. Thermoelectric Power . . . . .	214
6.12. Hall Coefficient . . . . .	217
6.13. Optical Constants . . . . .	222
6.14. Magnetic Susceptibility . . . . .	226
CHAPTER 7. VANADIUM . . . . .	229
7.1. Physical Constants and Room-Temperature Mechanical Properties . . . . .	229
7.2. Thermal Conductivity . . . . .	230
7.3. Specific Heat . . . . .	233
7.4. Thermal Linear Expansion . . . . .	236
7.5. Thermal Diffusivity . . . . .	240
7.6. Thermal Emittance . . . . .	242
7.7. Thermal Reflectance . . . . .	249
7.8. Thermal Absorptance, Transmittance, and Solar Absorptance to Emittance Ratio . . . . .	250
7.9. Viscosity . . . . .	251

	<u>Page</u>
7.10. Electrical Resistivity . . . . .	253
7.11. Thermoelectric Power . . . . .	257
7.12. Hall Coefficient . . . . .	259
7.13. Optical Constants . . . . .	262
7.14. Magnetic Susceptibility . . . . .	266
INDEX TO PROPERTIES AND MATERIALS . . . . .	269

# VOLUME III-2. PROPERTIES OF NONMETALLIC FLUID ELEMENTS

## TABLE OF CONTENTS

	<u>Page</u>
FOREWORD . . . . .	vii
PREFACE TO THE SERIES . . . . .	ix
INTRODUCTION . . . . .	xi
CHAPTER 1. GENERAL BACKGROUND . . . . .	1
1.1. Presentation of Data . . . . .	1
1.2. Introduction to Thermophysical Properties . . . . .	2
1.3. Data Evaluation and Generation of Recommended Values . . . . .	5
1.4. Symbols and Abbreviations . . . . .	7
1.5. Conversion Factors . . . . .	8
1.6. References . . . . .	10
CHAPTER 2. ARGON . . . . .	11
2.1. Physical Constants . . . . .	11
2.2. Specific Heat at Constant Pressure . . . . .	12
2.3. Thermal Conductivity . . . . .	14
2.4. Viscosity . . . . .	17
2.5. Prandtl Number . . . . .	20
2.6. References . . . . .	22
CHAPTER 3. BROMINE . . . . .	23
3.1. Physical Constants . . . . .	23
3.2. Specific Heat at Constant Pressure . . . . .	24
3.3. Thermal Conductivity . . . . .	25
3.4. Viscosity . . . . .	28
3.5. Prandtl Number . . . . .	30
3.6. References . . . . .	32
CHAPTER 4. CHLORINE . . . . .	33
4.1. Physical Constants . . . . .	33
4.2. Specific Heat at Constant Pressure . . . . .	33
4.3. Thermal Conductivity . . . . .	35
4.4. Viscosity . . . . .	38
4.5. Prandtl Number . . . . .	40
4.6. References . . . . .	42
CHAPTER 5. DEUTERIUM . . . . .	43
5.1. Physical Constants . . . . .	43
5.2. Specific Heat at Constant Pressure . . . . .	44
5.3. Thermal Conductivity . . . . .	46
5.4. Viscosity . . . . .	49
5.5. Prandtl Number . . . . .	52
5.6. References . . . . .	53

CHAPTER 6. FLUORINE . . . . .	55
6.1. Physical Constants . . . . .	55
6.2. Specific Heat at Constant Pressure . . . . .	56
6.3. Thermal Conductivity . . . . .	59
6.4. Viscosity . . . . .	62
6.5. Prandtl Number . . . . .	64
6.6. References . . . . .	66
CHAPTER 7. HELIUM 3. . . . .	67
7.1. Physical Constants . . . . .	67
7.2. Specific Heat at Constant Pressure . . . . .	67
7.3. Thermal Conductivity . . . . .	70
7.4. Viscosity . . . . .	72
7.5. Prandtl Number . . . . .	74
7.6. References . . . . .	75
CHAPTER 8. HELIUM 4. . . . .	77
8.1. Physical Constants . . . . .	77
8.2. Specific Heat at Constant Pressure . . . . .	78
8.3. Thermal Conductivity . . . . .	81
8.4. Viscosity . . . . .	84
8.5. Prandtl Number . . . . .	87
8.6. References . . . . .	88
CHAPTER 9. HYDROGEN, NORMAL . . . . .	89
9.1. Physical Constants . . . . .	89
9.2. Specific Heat at Constant Pressure . . . . .	90
9.3. Thermal Conductivity . . . . .	93
9.4. Viscosity . . . . .	96
9.5. Prandtl Number . . . . .	99
9.6. References . . . . .	100
CHAPTER 10. HYDROGEN, ORTHO . . . . .	101
10.1. Physical Constants . . . . .	101
10.2. Specific Heat at Constant Pressure . . . . .	101
10.3. Thermal Conductivity . . . . .	102
10.4. Viscosity . . . . .	103
10.5. Prandtl Number . . . . .	104
10.6. References . . . . .	104
CHAPTER 11. HYDROGEN, PARA . . . . .	105
11.1. Physical Constants . . . . .	105
11.2. Specific Heat at Constant Pressure . . . . .	106
11.3. Thermal Conductivity . . . . .	109
11.4. Viscosity . . . . .	112
11.5. Prandtl Number . . . . .	113
11.6. References . . . . .	114
CHAPTER 12. IODINE . . . . .	115
12.1. Physical Constants . . . . .	115
12.2. Specific Heat at Constant Pressure . . . . .	115
12.3. Thermal Conductivity . . . . .	117
12.4. Viscosity . . . . .	120
12.5. Prandtl Number . . . . .	123
12.6. References . . . . .	123
CHAPTER 13. KRYPTON . . . . .	125
13.1. Physical Constants . . . . .	125
13.2. Specific Heat at Constant Pressure . . . . .	126
13.3. Thermal Conductivity . . . . .	128
13.4. Viscosity . . . . .	131
13.5. Prandtl Number . . . . .	134
13.6. References . . . . .	135

CHAPTER 14. NEON . . . . .	137
14.1. Physical Constants . . . . .	137
14.2. Specific Heat at Constant Pressure . . . . .	138
14.3. Thermal Conductivity . . . . .	141
14.4. Viscosity . . . . .	143
14.5. Prandtl Number . . . . .	145
14.6. References . . . . .	147
CHAPTER 15. NITROGEN . . . . .	149
15.1. Physical Constants . . . . .	149
15.2. Specific Heat at Constant Pressure . . . . .	150
15.3. Thermal Conductivity . . . . .	152
15.4. Viscosity . . . . .	155
15.5. Prandtl Number . . . . .	158
15.6. References . . . . .	160
CHAPTER 16. OXYGEN . . . . .	161
16.1. Physical Constants . . . . .	161
16.2. Specific Heat at Constant Pressure . . . . .	162
16.3. Thermal Conductivity . . . . .	165
16.4. Viscosity . . . . .	168
16.5. Prandtl Number . . . . .	171
16.6. References . . . . .	174
CHAPTER 17. OZONE . . . . .	175
17.1. Physical Constants . . . . .	175
17.2. Specific Heat at Constant Pressure . . . . .	176
17.3. Thermal Conductivity . . . . .	177
17.4. Viscosity . . . . .	179
17.5. Prandtl Number . . . . .	180
17.6. References . . . . .	182
CHAPTER 18. RADON . . . . .	183
18.1. Physical Constants . . . . .	183
18.2. Thermal Conductivity . . . . .	184
18.3. References . . . . .	185
CHAPTER 19. TRITIUM . . . . .	187
19.1. Physical Constants . . . . .	187
19.2. Specific Heat at Constant Pressure . . . . .	187
19.3. Thermal Conductivity . . . . .	189
19.4. Viscosity . . . . .	192
19.5. Prandtl Number . . . . .	195
19.6. References . . . . .	196
CHAPTER 20. XENON . . . . .	197
20.1. Physical Constants . . . . .	197
20.2. Specific Heat at Constant Pressure . . . . .	198
20.3. Thermal Conductivity . . . . .	200
20.4. Viscosity . . . . .	203
20.5. Prandtl Number . . . . .	205
20.6. References . . . . .	207
INDEX TO PROPERTIES AND MATERIALS. . . . .	209

APPENDIX 2. TABLE OF CONTENTS OF THE COMPLETED DATA BOOK ENTITLED  
"VISCOSITY OF DENSE FLUIDS"

	<u>Page</u>
FOREWORD . . . . .	. 111
INTRODUCTION . . . . .	v
NOTATION . . . . .	1x

THEORY AND ESTIMATION

THEORY OF THE VISCOSITY OF DENSE GASES AND LIQUIDS . . . . .	3
Introduction . . . . .	3
Rigorous Statistical Mechanical Theories . . . . .	3
Theory of Corresponding States . . . . .	8
Model Theories . . . . .	9
EMPIRICAL ESTIMATION AND CORRELATION TECHNIQUES . . . . .	14
Introduction . . . . .	14
Empirical Correlation Equations . . . . .	14
Group Contribution Methods . . . . .	16
Correlation of Viscosity with Various Thermodynamic and Transport Properties . . . . .	16
REFERENCES TO TEXT . . . . .	18

NUMERICAL DATA

DATA PRESENTATION AND RELATED GENERAL INFORMATION . . . . .	27
Scope of Coverage . . . . .	27
Presentation of Data . . . . .	28
Symbols and Abbreviations Used in Figures and Tables . . . . .	30
Useful Physical Constants for the Reported Substances . . . . .	31
Conversion Factors for Units of Viscosity . . . . .	32
Conventions for Bibliographic Citation . . . . .	32

NUMERICAL DATA ON VISCOSITY  
(See Alphabetical Listing in Material Index)

TEXT, TABLES, AND FIGURES . . . . .	37
REFERENCES TO DATA SOURCES . . . . .	. 256

MATERIAL INDEX

MATERIAL INDEX . . . . .	. 267
--------------------------	-------



# APPENDIX 3

## TEPIAC TECHNICAL INQUIRY QUESTIONNAIRE

### QUESTIONNAIRE

(REQUIRED BY CINDAS SPONSORS - PLEASE RETURN)

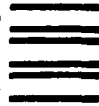
FROM:

\_\_\_\_\_ 19\_\_

NO POSTAGE  
NECESSARY  
IF MAILED  
IN THE  
UNITED STATES



1. How did you find out about us? ☐ from previous contact, ☐ a co-worker, ☐ TEPIAC Newsletters, ☐ Annual Report, ☐ referral from another center, ☐ recent publication, ☐ other (Explain item 8 below)
2. Did the information/data enclosed satisfy your needs? ☐ Very good, ☐ Adequate, ☐ Marginal.
3. Was the information/data timely to be useful? ☐ Yes, ☐ No, because: \_\_\_\_\_
4. Approximately how much time did the enclosed information/data save your research group? ☐ more than 40, ☐ 40-30 hours, ☐ 30-20 hours, ☐ 20-10 hours, ☐ 10-5 hours, ☐ 5-0 hours
5. The enclosed information/data will be used in: ☐ university research program, ☐ military programs, ☐ space programs, ☐ civilian equipment and design programs, ☐ materials selection, ☐ input to larger research studies, ☐ support in-house research, ☐ material for publication, ☐ proposal preparation, ☐ other (Explain item 8 below)
6. Are you on our Newsletter Mailing List? ☐ Yes, continue sending it to me, ☐ No, add my name to your list. Fill out the following:
  - a. Other communications of interest: ☐ Annual Report, ☐ Special announcements on publications/data tapes, ☐ Other (Explain item 8 below)
  - b. Your professional field: \_\_\_\_\_
  - c. Type industry: \_\_\_\_\_
  - d. Organizational function: \_\_\_\_\_  
(Examples: Corp Officer, Project Management, etc)
7. Was our charge reasonable for the service (product) provided? ☐ Too high, ☐ Reasonable, ☐ Too low.
8. Additional Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



**BUSINESS REPLY CARD**

FIRST CLASS PERMIT NO. 13 LAFAYETTE, INDIANA

POSTAGE WILL BE PAID BY ADDRESSEE

CINDAS/PURDUE UNIVERSITY  
Attn: Wade H. Shafer, Asst. Dir.  
2595 Yeager Road  
West Lafayette, IN 47906

# APPENDIX 4

## SURVEY RESULTS FROM TEPIAC TECHNICAL INQUIRY QUESTIONNAIRE

Between 1 July 1977 and 31 December 1979 (30 months), 1281 TEPIAC Technical Inquiry Questionnaires were mailed out with inquiry responses to inquirers. A total of 328 questionnaires were returned; this is a 25.6 percent return. There are eight questions listed in the questionnaire (see Appendix 3). The responses to each of the eight questions are detailed below.

### 1. How did you find out about us?

From a co-worker -----	84	(25.6%)
From a previous contact -----	60	(18.3%)
From TEPIAC Newsletters -----	52	(15.9%)
From TEPIAC recent publications -----	37	(11.3%)
Referral from another center -----	35	(10.7%)
From CINDAS Annual Reports -----	11	( 3.3%)
From other sources -----	49	(14.9%)
Total	328	

Typical "other sources" given in the responses are:

"Our information group"  
 "Reference librarian"  
 "Frequent use of your publications"  
 "Brochures mailed to me"  
 "CINDAS brochures"  
 "NTIS brochure"  
 "Critical survey of data sources, NBS (Dec. 75)"  
 "June issue of R/D magazine"  
 "CRC handbook"  
 "A US lecturer on medical physics"  
 "ASHRAE fundamentals book"  
 "Kruzas Encyclopedia of Information Systems and Services"  
 "At ASM Chicago Meeting 1977"  
 "Via North American Thermal Analysts Society (NATAS)"  
 "User Guide - DOD Information Analysis Center"  
 "National Bureau of Standards"  
 "Recommended by a Major Supplier"  
 "Article in May-June 1979 issue of National Defense"  
 "Lecture Series at Battelle"

### 2. Did the information/data enclosed satisfy your needs?

Very good -----	156	(51.2%)
Adequate -----	117	(38.3%)
Marginal -----	32	(10.5%)
Total	305 <sup>a</sup>	

### 3. Was the information/data timely to be useful?

Yes -----	258	(93.8%)
No (because no data are available) -----	17	( 6.2%)
Total	275 <sup>a</sup>	

4. Approximately how much time did the enclosed information/data save your research group?

5-0 hours -----	66	(38.7%)
More than 40 hours -----	45	(26.3%)
20-10 hours -----	24	(14.0%)
10-5 hours -----	24	(14.0%)
30-20 hours -----	12	( 7.0%)
Total	171 <sup>a</sup>	

5. The enclosed information/data will be used in:

Support in-house research -----	83	(25.3%)
Civilian equipment and design programs -----	49	(14.9%)
Input to larger research studies -----	42	(12.8%)
Materials selection -----	38	(11.6%)
Military programs -----	35	(10.7%)
Space programs -----	26	( 7.9%)
University research program -----	25	( 7.6%)
Material for publication -----	16	( 4.9%)
Proposal preparation -----	14	( 4.3%)
Total	328	

6. Are you on our Newsletter Mailing List?

No, add my name to your list -----	200	(68.3%)
Yes, continue sending it to me -----	93	(31.7%)
Total	293 <sup>a</sup>	

7. Was our charge reasonable for the service (product) provided?

Reasonable -----	183	(94.9%)
Too high -----	8 <sup>b</sup>	( 4.1%)
Too low -----	2	( 1.0%)
Total	193 <sup>a</sup>	

8. Additional Comments:

Typical "additional comments" given in the responses are:

"I was surprised that the information was found at all - let alone quickly"

"I received a very quick answer to my request for data on thermal expansion of steel"

"Very comprehensive work in your area"

"A tremendous amount of savings in time can be realized with the proper use of this valuable resource"

"Our own group unable to locate any references"

"We could not have done the job"

"We had exhausted all other possible sources"

"Estimate reduction of search time by 90 percent"

"We are regularly using Volumes 1-13 of the Thermophysical Properties of Matter - The TPRC Data Series; these volumes are extremely useful in our research"

"Very pleased with speed and accuracy of your reply"  
 "I appreciate the friendly and helpful manner you have when dealing with clients"  
 "Thank you for the assistance that you gave during our telephone conversation"  
 "You are fulfilling a very worthwhile service and we will continue to turn our service requirements your way"  
 "Brochures appear to have useful information to be utilized in materials selection for off shore petroleum production platforms"  
 "In the future I expect your service will be very helpful"  
 "We hope to use TEPIAC in the future"  
 "Our tendency is to turn to CINDAS only when all other information sources are inadequate, but it is reassuring to industries such as ours to have this back-up"  
 "The response from Mr. Shafer was rapid and to the point. I appreciate this type of response"  
 "You people write nice letters"  
 "This critical evaluation of research data is extremely valuable to the scientific and engineering communities"  
 "Appreciated the cordiality and helpfulness of Mr. Shafer"  
 "Your center has repeatedly been referenced as a prime source of information in my area of research"  
 "I foresee a need for this type of service in the future - next time I will start with TEPIAC search"  
 "You offer a valuable service which is much appreciated"  
 "Very honest and reasonable data source"  
 "Estimate man-hour savings at 400 hours per year"  
 "Saved our lab testing time more than 40 hours"  
 "Very pleased with searches"  
 "Your objectives are very important and of great help to science and engineering fields"  
 "Very quick response"  
 "The service is fast and reliable, it should be better known"  
 "Service is excellent"  
 "Your people were very helpful and I will use your organization when needed"  
 "Prompt service was much appreciated"

<sup>a</sup> "No responses" are not included in the statistics - a total of 328 questionnaires were returned.

<sup>b</sup> Six of the eight responses saying the charge being too high were from university students/faculty members and small company employees.

## APPENDIX 5

### ORGANIZATIONS USING TEPIAC INQUIRY SERVICES<sup>a</sup>

(In the Period 1 October 1975 to 31 December 1979)

AAI Corp. Baltimore, MD	Air Force Weapons Laboratory Kirkland Air Force Base, NM
A. B. Chance Co. Centralia, MO	Air Products and Chemical Co. Allentown, PA
ACRES American Buffalo, NY	AIRCO, Inc. Murray Hill, NJ
Action Research Acton, MA	Air Research Manufacturing Phoenix, AZ
Actron, Inc. Monrovia, CA	Alabama A & M University Huntsville, AL
Acurex Corp. Mountain View, CA	Alabama A & M University Normal, AL
Aero Mechanical Engr. Lab. Tucson, AZ	Allegheny Ballistics Laboratory Cumberland, MD
Aerojet Electrosystems Azusa, CA	Allegheny Ludlum Steel Corp. Pittsburgh, PA
Aerojet Nuclear Co. Idaho Falls, ID	Allied Chemical Co. Idaho Falls, ID
Aerospace Corp. Los Angeles, CA	Allied Chemical Corp. Morristown, NJ
Aerospace Research Applications Center Indianapolis, IN	Aluminum Company of America Alcoa Center, PA
Air Force Avionics Lab. Wright-Patterson Air Force Base, OH	American Home Foods, Inc. LaPorte, IN
Air Force Materials Laboratory Wright-Patterson Air Force Base, OH	American Iron and Steel Institute Washington, DC
Air Force Office of Scientific Research Bolling Air Force Base, DC	American Thermocraft Corp. East Orange, NJ
Air Force Rocket Propulsion Laboratory Edwards Air Force Base, CA	AMF Incorporated Stanford, CT

<sup>a</sup> Only organizations within the United States are listed.

Amoco Chemical Co.  
Naperville, IL

AMP Incorporated  
Harrisburg, PA

Anaconda Brass Co.  
Waterbury, CT

Anaconda Co.  
Marion, IN

Anamet Lab., Inc.  
San Carlos, CA

Argonne National Laboratories  
Argonne, IL

Arizona State University  
Tempe, AZ

Army Materials & Mechanics Research Center  
Watertown, MA

Arthur D. Little, Inc.  
Cambridge, MA

Ashland Chemical Co.  
Columbus, OH

Asin Seiki Co., Ltd.  
Troy, MI

Atlantic Research Center  
Alexandria, VA

Atlantic Richfield Hartford Co.  
Richland, WA

Atomic Energy Documentation Service  
Larchmont, NY

Atomic International  
Canoga Park, CA

Autonetics, Inc.  
Anaheim, CA

Babcock & Wilcox, Research & Development  
Alliance, OH

Babcock & Wilcox Co.  
Lynchburg, VA

Baker & Taylor Co.  
Mokense, IL

Baker & Taylor Co.  
Somerville, NJ

Ball Corp.  
Muncie, IN

Barber Colman Co.  
Loves Park, IL

Bartlesville Energy Research Center  
Bartlesville, OK

Battelle Columbus Laboratories  
Columbus, OH

Battelle-Northwest  
Richland, WA

BDM Corp.  
Dayton, OH

Bechtel Corp.  
San Francisco, CA

Bechtel Power Co.  
San Francisco, CA

Bechtel Tower Corp.  
Gaithersburg, MD

Bell Aerospace/Textron  
Buffalo, NY

Bell Laboratories  
Allentown, PA

Bell Telephone Laboratories, Inc.  
Murray Hill, NJ

Bendix Corp.  
Dayton, OH

Bendix Corp.  
Davenport, IA

Bendix Corp.  
Kansas City, MO

Bendix Research Laboratory  
South Field, MI

Bettis Atomic Power Laboratories  
W. Mifflin, PA

Black and Veatch, Inc.  
Kansas City, MO

Boeing Aerospace Co.  
Houston, TX

Boeing Co.  
Seattle, WA

Boeing Computer Services  
Richland, WA

Borg Warner Corp.  
Des Plaines, IL

Breed Corp.  
Fairfield, NJ

Bresler and Associates  
New York, NY

Bricmont & Associates, Inc.  
McMurray, PA

Brigham Young University  
Provo, UT

Brockway Glass Co.  
Brockway, PA

Brookhaven National Laboratories  
Upton, NY

BRL/Aberdeen Proving Ground  
Aberdeen, MD

Brunswick Corp.  
Skokie, IL

Bunker Ramo Corp.  
Chatsworth, CA

Burns and Roe Co.  
Hempstead, NY

Burroughs Corp.  
San Diego, CA

CABOT Corp.  
Billerica, MA

California Institute of Technology  
Pasadena, CA

California State University  
Fullerton, CA

Calspan Corp.  
Buffalo, NY

Carborundum Co.  
Niagara Falls, NY

Carnegie Mellon University  
Pittsburgh, PA

Carrier Corp./Research Division  
Syracuse, NY

Carson Alexion Corp.  
Costa Mesa, CA

Case Western Reserve University  
Cleveland, OH

Caterpillar Tractor Co.  
Peoria, IL

Catholic University  
Washington, DC

CHEMETAL Corp.  
Pacoima, CA

Chem. Shore Corp.  
Houston, TX

Chicago Urban Transportation District  
Chicago, IL

Chi-Vit Co.  
Oakbrook, IL

Chrysler Corp.  
Detroit, MI

Cincinnati Electronics Corp.  
Cincinnati, OH

Cincinnati Inc.  
Cincinnati, OH

Climax Molybdenum Co.  
Ann Arbor, MI

Colorado State University  
Fort Collins, CO

Columbia Gas Systems  
Columbus, OH

Columbia University  
New York, NY

Combustion Engineering  
Chattanooga, TN

COMSAT Laboratories  
Clarksburg, MD

Consolidated Aluminum Service Center  
St. Louis, MO

Cordis Corp.  
Miami, FL

Cornell University  
Ithaca, NY

Cornell University  
Utica, NY

Corning Glass Works  
Corning, NY

Coulter Systems Corp.  
Bedford, MA

CS Draper & Laboratory  
Cambridge, MA

CTI Cryogenics  
Waltham, MA

Curtiss-Wright Corp.  
Woodridge, NJ

Daniel Construction Co.  
Greenville, SC

DCM Associates  
San Francisco, CA

Deere and Co.  
Moline, IL

Defense Logistics Agency  
Alexandria, VA

Department of Transportation  
Washington, DC

Department of Interior Library  
Washington, DC

Dert Industries  
Paramus, NY

Desota, Inc.  
Des Plaines, IL

Detrick Co.  
Chicago, IL

Deutch Co.  
Los Angeles, CA

DIGICOLOR  
Columbus, OH

Dixie College  
St. George, UT

Dow Chemical Co.  
Freeport, TX

Dow Chemical Co.  
Midland, MI

DuPont Instruments  
Wilmington, DE

DuPont de Nemours & Co.  
Wilmington, DE

Eastman Kodak Co.  
Rochester, NY

E.G. & G. Idaho Inc.  
Idaho Falls, ID

Electric Furnace Co.  
Salem, OH

Electronic Technology  
Hanscom Air Force Base, MA

El Paso Products Co.  
Odessa, TX

Emerson Electric Inc.  
St. Louis, MO



Emory University  
Atlanta, GA

Energy Conservation System  
Warren, MI

Energy Resources Co.  
Cambridge, MA

Engelhard Chemical Corp.  
Carteret, NJ

Engineering Systems Co.  
Damascus, MD

Enirex Corp.  
Patterson, NJ

Environment Information Center  
New York, NY

E-Systems Inc.  
Greenville, TX

Explosive Technology  
Fairfield, CA

Exxon Nuclear Co.  
Richland, WA

Exxon Prod. Research Co.  
Houston, TX

Exxon Research Center  
Linden, NJ

Fairchild Space & Electronics Co.  
Germantown, MD

Fiber Materials, Inc.  
Biddeford, MA

Fluids Systems Laboratory  
West Lafayette, IN

Ford Aerospace Co.  
Newport Beach, CA

Ford Aerospace Corp.  
Palo Alto, CA

Ford Motor Co.  
Detroit, MI

Forester-Monell Engr. Associates, Inc.  
Colorado Springs, CO

Foundation Sciences, Inc.  
Portland, OR

Foxboro Co.  
Foxboro, MA

FWG Associates  
Tullahoma, TN

Gale Research Co.  
Detroit, MI

Garrett Corp.  
Los Angeles, CA

General American Co.  
Niles, IL

General Atomic Co.  
San Diego, CA

General Dynamics/Convair  
San Diego, CA

General Dynamics Corp.  
Pomona, CA

General Electric Co.  
Cleveland, OH

General Electric Co.  
Hendersonville, TN

General Electric Co.  
Philadelphia, PA

General Electric Co.  
San Jose, CA

General Electric Co.  
Syracuse, NY

General Electric Co.  
Worthington, OH

General Electric Research Laboratory  
Schenectady, NY

General Electric Space Division  
Cincinnati, OH

General Foods Corp.  
Tarrytown, NY

General Motors Corp.  
Indianapolis, IN

General Motors Technical Center  
Warren, MI

General Research Corp.  
McLean, VA

General Telephone & Electronics Labs.  
Waltham, MA

Georgia Institute of Technology  
Atlanta, GA

Georgia Power Co.  
Forest Park, GA

Gillette Co.  
Boston, MA

Global Engr. Documentation Services, Inc.  
Santa Ana, CA

Goodyear Aerospace Inc.  
Akron, OH

Goddard Space Flight Center  
Greenbelt, MD

Gould Inc.  
El Monte, CA

GPK Products Inc.  
Fargo, ND

Grandfield Associates  
Santa Barbara, CA

Great Lakes Research Corp.  
Elizabethton, TN

Grumman Aerospace Corp.  
Bethpage, NY

Guest Associates  
Huntsville, AL

Gulf Science & Technology Co.  
Pittsburgh, PA

Hadden Group Inc.  
Miami, FL

Hague International  
South Portland, ME

Harris Thermal Transfer Products, Inc.  
St. Tualatin, OR

Harrison Radiator Division/GM Corp.  
Lockport, NY

Hercules Inc.  
Magna, UT

Hercules Inc.  
Washington, PA

Hewett-Packard Inc.  
Boise, ID

Hewett-Packard Co.  
Palo Alto, CA

Hitco Corp.  
Gardena, CA

Honeywell Radiation Center  
Lexington, MA

Honeywell Research Center  
Bloomington, MN

Hooker Chemical Co.  
Niagara Falls, NY

Horizons Research Inc.  
Cleveland, OH

Hughes Aircraft Co.  
Culver City, CA

Hughes Research Library  
Malibu, CA

Huntington Alloys, Inc.  
Huntington, WV

IBM Corp.  
Columbus, OH

IBM Corp.  
Poughkeepsie, NY

IBM Corp.  
Raleigh, NC

IBM Corp.  
San Jose, CA

IBM/Materials Laboratory  
Endicott, NY

Idaho State University  
Pocatello, ID

Illinois State Water Survey  
Urbana, IL

Indiana University  
Bloomington, IN

Indium Corp. of America  
Utica, NY

Indland Division/GM Corp.  
Dayton, OH

Ingersol Rand Research Inc.  
Princeton, NJ

Inland Steel Research Laboratory  
E. Chicago, IN

Institute of Gas Technology  
Chicago, IL

International Applied Physics Inc.  
Dayton, OH

The International Nickel Co.  
Suffern, NY

Interpace Inc.  
Los Angeles, CA

Iowa State University  
Ames, IA

Irons & Sears  
Washington, DC

IRTA Corp.  
San Diego, CA

ITEX Corp.  
Lexington, MA

ITEK Corp.  
Sunnyvale, CA

ITT Research Institute  
Chicago, IL

Jet Propulsion Laboratory  
Pasadena, CA

John Deere Technical Center  
Moline, IL

John Hopkins University  
Baltimore, MD

John Hopkins University  
Laurel, MD

Kanthal Corp.  
Bethel, CT

KAWECKI BERYLCO Industries Inc.  
Reading, PA

Kent State University  
Ashtabula, OH

Keystone Carbon Company  
St. Marys, PA

LAND Instruments Inc.  
Tullytown, PA

Lamar University  
Beaumont, TX

Langley Research Center  
Hampton, VA

Laser Analytics, Inc.  
Lexington, MA

Lawrence Berkeley Laboratory  
Berkeley, CA

Lawrence Livermore Laboratory  
Livermore, CA

LEAR-SIEGLAR, Inc.  
Grand Rapids, MI

Libby Owens Ford Co.  
Toledo, OH

Library of Congress  
Science and Technology Division  
Washington, DC

Lockheed Corp.  
Burbank, CA

Lockheed Missile & Space Co.  
Huntsville, AL

Lockheed Missiles & Space Co.  
Sunnyvale, CA

Los Alamos Scientific Laboratories  
Los Alamos, NM

LUWA Corp.  
Charlott, NC

Marathon Oil Co.  
Littleton, CO

Marquardt Co.  
Van Nuys, CA

Marsh Products, Inc.  
Batavia, IL

Marshall Space Flight Center  
Huntsville, AL

Martin Marietta Corp.  
Baltimore, MD

Martin Marietta Corp.  
Orland, FL

Massachusetts Institute of Technology  
Cambridge, MA

Massey Engineering  
Fort Atkinson, WI

Materials Research Corp.  
Orangeburg, NY

Materials Research Corp.  
Pearl River, NY

Materials Science Corp.  
Blue Bell, PA

McDonald Astronautics Co.  
St. Louis, MO

McDonnell Douglas Corp.  
St. Louis, MO

McGraw Edison Co.  
Columbia, MO

Mechanical Technology Inc.  
Latham, NY

Metals Research Corp.  
Waterbury, CT

Metals Research Laboratory  
New Haven, CT

Micropac Industries, Inc.  
Garland, TX

Midwest Library Service  
Maryland Heights, MO

Millersville State College  
Millersville, PA

Mission Research Center  
Santa Barbara, CA

MIT Lincoln Laboratories  
Lexington, MA

Montana College of Mining, Science,  
and Technology  
Butte, MT

Montana Energy Institute Inc.  
Butte, MT

Montana State University  
Bozeman, MT

NASA Ames Research Center  
Moffett Field, CA

NASA Lewis Research Center  
Cleveland, OH

Nashua Corp.  
Nashua, NH

National Association of Home Builders  
Rockville, MD

National Bureau of Standards  
Washington, DC

National Homes Corp.  
Lafayette, IN

National Institute of Health  
Bethesda, MD

National Materials Advisory Board/NAS  
Washington, DC

National Metallizing Division  
Cranbury, NJ

National Oceanic-Atmos. Administration  
Boulder, CO

National Science Foundation  
Washington, DC

National Semiconductor Corp.  
Santa Clara, CA

National Water Lift Co.  
Kalamazoo, MI

Naval Air Development Center  
Warmister, PA

Naval Construction Battalion Center  
Port Hueneme, CA

Naval Material Command  
Washington, DC

Naval Research Laboratory  
Washington, DC

Naval Ship R & D Center  
Annapolis, MD

Naval Surface Weapons Center  
Silver Springs, MD

Naval Undersea Center  
San Diego, CA

Naval Underwater Systems Command  
Newport, RI

Naval Weapons Center  
China Lake, CA

Naval Weapons Support Center  
Crane, IN

New England Research Center  
Sudbury, MA

Newport Metals Co.  
Newport, RI

Night Vision Laboratory  
Fort Belvoir, VA

NL Industries  
Niagra Falls, NY

Northrop Corp. Aircraft Gp.  
Hawthorne, CA

NWI International  
La Grange, IL

Oak Ridge National Laboratories  
Oak Ridge, TN

Occidental Chemical Co.  
Plainview, TX

Occidental Research Corp.  
Irvine, CA

O'Donnall & Associates  
Pittsburgh, PA

Ohio State University  
Columbus, OH

Oklahoma State University  
Stillwater, OK

Old Dominion University  
Norfolk, VA

Olin Corp.  
New Haven, CT

Owens Corning Fiberglass Co.  
Granville, OH

Pacific Missile Test Center  
Point Mugu, CA

PECO Manufacturing Co.  
Portland, OR

Pennsylvania State University  
University Park, PA

Pennwalt Corp.  
King of Prussia, PA

Perkin-Elmer Corp.  
Norwalk, CT

Philips Laboratory  
Briarcliff Manner, NY

Phillips Chemical Co.  
Phillips, TX

Phillips Petroleum Co.  
Bartlesville, OK

Picatinny Arsenal  
Dover, NJ

Picker Dunlee Corp.  
Bellwood, IL

Polycold Systems Inc.  
San Rafael, CA

PPG Industries  
Barberton, OH

PPG Industries  
Corpus Christi, TX

PPG Industries  
Pittsburgh, PA

PPG Industries  
Shelby, NC

Pratt and Whitney Aircraft Co.  
E. Hartford, CT

Pratt and Whitney Aircraft Co.  
West Palm Beach, FL

Princeton Combustion Research Laboratory  
Princeton, NJ

Princeton University  
Princeton, NJ

Pullman Kellogg Co.  
Houston, TX

Purdue University  
West Lafayette, IN

Pyrometer Instrumentation  
North Vale, NJ

Rand Corp.  
Santa Monica, CA

Raytheon Corp.  
Bedford, MA

Raytheon Corp.  
Wayland, MA

Raytek, Inc.  
Mountain View, CA

RCA Astro-Electronics  
Princeton, NJ

RCA Corp.  
Indianapolis, IN

Rensselaer Polytechnic Institute  
Troy, NY

Reynolds Metals Co.  
Richmond, VA

Rice University  
Houston, TX

Richardson Co.  
Melrose Park, IL

Rockwell International Corp.  
Downey, CA

Rogers Corp.  
Rogers, CT

Roll Manufacturing Institute  
Pittsburgh, PA

Rovac Corp.  
Rockledge, FL

Salem Furnace Co.  
Pittsburgh, PA

Sanders Associates, Inc.  
Nashua, NH

Sandia Laboratories  
Albuquerque, NM

Sandy Hill Co.  
Hudson Falls, NY

Santa Barbara Research Center  
Gobietta, CA

Scandinavian Documentation Center  
Washington, DC

Science Application, Inc.  
McLean, VA

Smithsonian Scientific Information  
Exchange, Inc.  
Washington, DC

Solar Energy Laboratory  
Houston, TX

Solar Energy Laboratory  
Madison, WI

Solar Energy Research  
Golden, CO

Solar Power Corp.  
North Billerica, MA

Solar Turbines International  
San Diego, CA

SPERRY Flight Systems  
Phoenix, AZ

SPERRY Rand Corp.  
Jackson, MS

STACO Inc.  
Dayton, OH

Standard Oil Co.  
Cleveland, OH

Standard Oil Research Center  
Naperville, IL

Stanford Research Institute  
Menlo Park, CA

Stanford University  
Stanford, CA

State University of New York  
Plattsburgh, NY

Stauffer Chemical Co.  
Dobbs Ferry, NY

Stellite Co.  
Kokomo, IN

Stevens Institute of Technology  
Hoboken, NJ

Structural Composites Industries, Inc.  
Azusa, CA

Southern Illinois University  
Edwardsville, IL

Syracuse University  
Syracuse, NY

Systems Consultants  
Rosslyn, VA

Technical Information Center/TRW Systems  
Redondo Beach, CA

Technicon Corp.  
Tarrington, NY

Technology Information Sources Center  
Los Angeles, CA

Tekronix, Inc.  
Beaverton, OR

Teledyne Energy Systems  
Baltimore, MD

Teledyne Rodney Metals  
New Bedford, MA

Teledyne Systems Co.  
Northridge, CA

Teledyne Turbine Engines  
Toledo, OH

Teledyne Vasco  
Latrobe, PA

Tenneco Chemicals  
Piscataway, NJ

TERATEK Co.  
Salt Lake City, UT

Texas Instruments, Inc.  
Dallas, TX

Thermax Systems Inc.  
Costa Mesa, CA

Thiokol, Inc.  
Brigham City, UT

Timex Corp.  
Cupertino, CA

Titanium Metals Corp.  
Pittsburgh, PA

Total Information  
Rochester, NY

Total Systems Inc.  
Downers Grove, IL

TRACOR, Inc.  
Austin, TX

TRW Systems  
Redondo Beach, CA

TSI Inc.  
St. Paul, MN

Union Carbide Corp.  
Bound Brook, NJ

Union Carbide Corp.  
Indianapolis, IN

Union Carbide Corp.  
Oak Ridge, TN

Union Carbide Corp.  
Paducah, KY

Union Oil Co.  
Santa Rosa, CA

United States Steel Corp.  
Monroeville, PA

United Technologies Inc.  
East Hartford, CT

United Technology Corp.  
Middletown, CT

University of Arkansas  
Fayetteville, AR

University of Arizona  
Tucson, AZ

University of California  
Berkeley, CA

University of California  
Davis, CA

University of California  
Los Angeles, CA

University of Colorado  
Boulder, CO

University of Dayton  
Dayton, OH

University of Delaware  
Neward, DE

University of Hawaii  
Honolulu, Hawaii

University of Illinois  
Urbana, IL

University of Kentucky  
Lexington, KY

University of Louisville  
Louisville, KY

University of Maryland  
College Park, MD

University of Michigan  
Ann Arbor, MI

University of Minnesota  
Minneapolis, MN

University of Missouri-Rolla  
Rolla, MO

University of New Mexico  
Albuquerque, NM

University of North Carolina  
Chapel Hill, NC



University of North Dakota  
Grand Forks, ND

University of Puerto Rico  
Mayaguez, Puerto Rico

University of Rhode Island  
Kingston, RI

University of Rochester  
Rochester, NY

University of South Florida  
Tampa, FL

University of Southern California  
Los Angeles, CA

University of Texas  
Austin, TX

University of Utah  
Salt Lake City, UT

University of Wisconsin  
Wausau, WI

University of Washington  
Seattle, WA

U.S. Army (ADRAD-COM)  
Fort Eustis, VA

U.S. Army Electronics Command  
Fort Monmouth, NJ

U.S. Army Engr. Waterways  
Experiment Station  
Vicksburg, MS

U.S. Army/FSTC  
Charlottesville, VA

U.S. Army Material Command  
Alexandria, VA

U.S. Army Missile Command  
Redstone Arsenal  
Huntsville, AL

U.S. Army Prod. Equip. Agency  
Rock Island, IL

U.S. Bureau of Mines  
Albany, OR

U.S. Bureau of Mines  
Twin Cities, MN

U.S. Environmental Protection Agency  
Washington, DC

U.S. General Accounting Office  
Denver, CO

Valeron Corp.  
Oak Park, MI

Vallecitos Nuclear Center  
Pleasanton, CA

Valley Forge Space Technical Center  
Philadelphia, PA

Vega Industries, Inc.  
Des Moines, IA

Versar Inc.  
Springfield, VA

Vetco Offshore Inc.  
Ventura, CA

Vought Corp.  
Dallas, TX

Watervliet Arsenal  
Watervliet, NY

Watkins Johnson Co.  
Palo Alto, CA

Westinghouse Electric Corp.  
Baltimore, MD

Westinghouse Electric Corp.  
Pittsburgh, PA

Westinghouse Electric Research Lab.  
West Lafayette, IN

Westinghouse Hanford Co.  
Richland, WA

Westinghouse R & D Center  
Pittsburgh, PA

Westinghouse Research Laboratory  
Pittsburgh, PA

Williams Research Corp.  
Walled Lake, MI

W.L. Tanksley Associates  
Cleveland, OH

W.R. Grace and Co.  
Columbia, MD

Wyman Gordon Co.  
Worcester, MA

Xerox Corp.  
El Segundo, CA

Xerox Corp.  
Rochester, NY

Xerox Research Laboratory  
Webster, NY

Yale University  
New Haven, CT

Yellow Springs Instruments  
Yellow Springs, OH

3M Technical Center  
St. Paul, MN

# DISTRIBUTION LIST

Army Materials & Mechanics Research Center  
ATTN: DRXMR-P/Mr. S. Valencia  
Arsenal Street  
Watertown, Massachusetts 02172 (2)

Defense Logistics Agency  
ATTN: DLA-SCT/Mr. J.L. Blue  
Cameron Station  
Alexandria, Virginia 22314 (2)

Defense Electronics Supply Center  
ATTN: PAEC/Mrs. F. Burke  
1507 Wilmington Pike  
Dayton, Ohio 45444 (1)

ONRRR  
The Ohio State University Research Center  
1314 Kinnear Road  
Columbus, Ohio 43212 (1)

Defense Technical Information Center  
Cameron Station  
Alexandria, Virginia 22314 (2)

Mr. Jerome Persh  
Office of Under Secretary of Defense  
for Research and Engineering  
Room 3D1089, The Pentagon  
Washington, D.C. 20301 (1)

Chemical Propulsion Information Agency  
ATTN: Mr. R.D. Brown  
The Johns Hopkins University  
8621 Georgia Avenue  
Silver Spring, Maryland 20910 (1)

Infrared Information and Analysis Center  
ATTN: Dr. G.J. Zissis  
Environmental Research Institute of  
Michigan  
P.O. Box 618  
Ann Arbor, Michigan 48107 (1)

Machinability Data Center  
ATTN: Dr. J.F. Kahles  
3980 Rosslyn Drive  
Cincinnati, Ohio 45209 (1)

Mechanical Properties Data Center  
ATTN: Mr. H. Mindlin  
Battelle-Columbus Laboratories  
505 King Avenue  
Columbus, Ohio 43201 (1)

Metals and Ceramics Information Center  
ATTN: Mr. H. Mindlin  
Battelle-Columbus Laboratories  
505 King Avenue  
Columbus, Ohio 43201 (1)

Nondestructive Testing Information  
Analysis Center  
ATTN: Dr. R.T. Smith  
Southwest Research Institute  
8500 Culebra Road  
San Antonio, Texas 78284 (1)

Plastics Technical Evaluation Center  
ATTN: Mr. H.E. Pebly  
Picatinny Arsenal  
Dover, New Jersey 07801 (1)

Reliability Analysis Center  
ATTN: Mr. H.A. Lauffenburger  
Rome Air Development Center  
Griffiss Air Force Base,  
New York 13440 (1)

Thermophysical and Electronic Properties  
Information Analysis Center  
ATTN: Dr. Y.S. Touloukian  
CINDAS/Purdue University  
2595 Yeager Road  
West Lafayette, Indiana 47906 (1)

Coastal Engineering Information  
Analysis Center  
ATTN: Mr. D.W. Berg  
Kingman Building  
Ft. Belvoir, Virginia 22060 (1)

Cold Regions Science & Technology  
Information Analysis Center  
ATTN: Mr. W. Pietkiewicz  
Cold Regions Research & Engineering  
Laboratory  
Hanover, New Hampshire 03755 (1)

# DISTRIBUTION LIST (continued)

Concrete Technology Information  
Analysis Center  
ATTN: Mr. B. Mather  
Army Engineer Waterways Experiment  
Station  
P.O. Box 631  
Vicksburg, Mississippi 39180

(1)

DOD Nuclear Information and  
Analysis Center  
ATTN: Mrs. Terri Egan  
General Electric-TEMPO  
816 State Street  
P.O. Drawer QQ  
Santa Barbara, California 93102

(1)

Hydraulic Engineering Information  
Analysis Center  
ATTN: Mr. E.B. Pickett  
Army Engineer Waterways Experiment  
Station  
P.O. Box 631  
Vicksburg, Mississippi 39180

(1)

Pavement and Solids Trafficability  
Information Analysis Center  
ATTN: Mr. M.P. Meyer  
Army Engineer Waterways Experiment  
Station  
P.O. Box 631  
Vicksburg, Mississippi 39180

(1)

Shock and Vibration Information Center  
ATTN: Mr. H.C. Pusey  
Naval Research Laboratory  
Code 6020  
Washington, D.C. 20390

(1)

Soil Mechanics Information Analysis  
Center  
ATTN: Mr. R.W. Cunny  
Army Engineer Waterways Experiment  
Station  
P.O. Box 631  
Vicksburg, Mississippi 39180

(1)

Tactical Technology Center  
ATTN: Mr. J.T. Brown  
Battelle-Columbus Laboratories  
505 King Avenue  
Columbus, Ohio 43201

(1)

Tactical Weapon Guidance and Control  
Information and Analysis Center  
ATTN: Mr. C. Smoots  
IIT Research Institute  
10 West 35th Street  
Chicago, Illinois 60616

(1)

Col. Andrew A. Aines (Ret.)  
Office of the Deputy Under Secretary  
of Defense for Research and  
Advanced Technology  
Room 3B259, The Pentagon  
Washington, D.C. 20301

(1)

Air Force Materials Laboratory  
ATTN: AFML-MXE/Mr. L.S. Theibert  
Nonmetals Engineering Branch  
System Support Division  
Wright Patterson AFB, OH 45433

(1)

Mr. H.E. Sauter, Administrator  
Defense Technical Information Center  
Cameron Station  
Alexandria, Virginia 22314

(1)

Mr. J.F. Pendergast (DTIC-AI)  
Defense Technical Information Center  
Cameron Station  
Alexandria, Virginia 22314

(1)

<p>Army Materials and Mechanics Research Center, Watertown, Massachusetts 02172 THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC) - A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906 Technical Report AMMRC TR 80-15, March 1980, 111 pp-illus-tables, Contract DLA900-79-C-1007 Annual Final Report, 1 January to 31 December 1979</p>	<p>AD UNCLASSIFIED UNLIMITED DISTRIBUTION</p> <p>Key Words Thermophysical properties Electronic properties Electrical properties Magnetic properties Optical properties Information Analysis Center Data compilation, evaluation, analysis, and synthesis</p>	<p>This Annual Final Report covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. It is one of the most efficient and cost-effective Full-Service DOD Information Analysis Centers. During this 12-month reporting period, TEPIAC has screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 documents while completely overhauling the system, compiled 2,675 sets of property data, responded to 562 inquiries, published or completed 5 volumes of data books with a total of 1,833 pages, 2 technical reports with a total of 396 pages, and 10 volumes of research literature retrieval guides with a total of 3,097 pages, and distributed 66,000 copies in 6 issues of the "Thermophysics and Electronics Newsletter."</p>
<p>Army Materials and Mechanics Research Center, Watertown, Massachusetts 02172 THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC) - A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906 Technical Report AMMRC TR 80-15, March 1980, 111 pp-illus-tables, Contract DLA900-79-C-1007 Annual Final Report, 1 January to 31 December 1979</p>	<p>AD UNCLASSIFIED UNLIMITED DISTRIBUTION</p> <p>Key Words Thermophysical properties Electronic properties Electrical properties Magnetic properties Optical properties Information Analysis Center Data compilation, evaluation, analysis, and synthesis</p>	<p>This Annual Final Report covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. It is one of the most efficient and cost-effective Full-Service DOD Information Analysis Centers. During this 12-month reporting period, TEPIAC has screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 documents while completely overhauling the system, compiled 2,675 sets of property data, responded to 562 inquiries, published or completed 5 volumes of data books with a total of 1,833 pages, 2 technical reports with a total of 396 pages, and 10 volumes of research literature retrieval guides with a total of 3,097 pages, and distributed 66,000 copies in 6 issues of the "Thermophysics and Electronics Newsletter."</p>
<p>Army Materials and Mechanics Research Center, Watertown, Massachusetts 02172 THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC) - A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906 Technical Report AMMRC TR 80-15, March 1980, 111 pp-illus-tables, Contract DLA900-79-C-1007 Annual Final Report, 1 January to 31 December 1979</p>	<p>AD UNCLASSIFIED UNLIMITED DISTRIBUTION</p> <p>Key Words Thermophysical properties Electronic properties Electrical properties Magnetic properties Optical properties Information Analysis Center Data compilation, evaluation, analysis, and synthesis</p>	<p>This Annual Final Report covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. It is one of the most efficient and cost-effective Full-Service DOD Information Analysis Centers. During this 12-month reporting period, TEPIAC has screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 documents while completely overhauling the system, compiled 2,675 sets of property data, responded to 562 inquiries, published or completed 5 volumes of data books with a total of 1,833 pages, 2 technical reports with a total of 396 pages, and 10 volumes of research literature retrieval guides with a total of 3,097 pages, and distributed 66,000 copies in 6 issues of the "Thermophysics and Electronics Newsletter."</p>

<p>Army Materials and Mechanics Research Center Watertown, Massachusetts 02172 THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC) - A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906</p> <p>Technical Report AM98C TR 80-15, March 1980, 111 pp-illus-tables, Contract DLA900-79-C-1007 Annual Final Report, 1 January to 31 December 1979</p> <p>This Annual Final Report covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. It is one of the most efficient and cost-effective Full-Service DOD Information Analysis Centers. During this 12-month reporting period, TEPIAC has screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 documents while completely overhauling the system, compiled 2,675 sets of property data, responded to 562 inquiries, published or completed 5 volumes of data books with a total of 1,833 pages, 2 technical reports with a total of 396 pages, and 10 volumes of research literature retrieval guides with a total of 3,097 pages, and distributed 66,000 copies in 6 issues of the "Thermophysics and Electronics Newsletter."</p>	<p>AD</p> <p>UNCLASSIFIED UNLIMITED DISTRIBUTION</p> <p>Key Words Thermophysical properties Electronic properties Electrical properties Magnetic properties Optical properties Information Analysis Center Data compilation, evaluation, analysis, and synthesis</p>
<p>Army Materials and Mechanics Research Center Watertown, Massachusetts 02172 THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC) - A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906</p> <p>Technical Report AM98C TR 80-15, March 1980, 111 pp-illus-tables, Contract DLA900-79-C-1007 Annual Final Report, 1 January to 31 December 1979</p> <p>This Annual Final Report covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. It is one of the most efficient and cost-effective Full-Service DOD Information Analysis Centers. During this 12-month reporting period, TEPIAC has screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 documents while completely overhauling the system, compiled 2,675 sets of property data, responded to 562 inquiries, published or completed 5 volumes of data books with a total of 1,833 pages, 2 technical reports with a total of 396 pages, and 10 volumes of research literature retrieval guides with a total of 3,097 pages, and distributed 66,000 copies in 6 issues of the "Thermophysics and Electronics Newsletter."</p>	<p>AD</p> <p>UNCLASSIFIED UNLIMITED DISTRIBUTION</p> <p>Key Words Thermophysical properties Electronic properties Electrical properties Magnetic properties Optical properties Information Analysis Center Data compilation, evaluation, analysis, and synthesis</p>
<p>Army Materials and Mechanics Research Center Watertown, Massachusetts 02172 THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC) - A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906</p> <p>Technical Report AM98C TR 80-15, March 1980, 111 pp-illus-tables, Contract DLA900-79-C-1007 Annual Final Report, 1 January to 31 December 1979</p> <p>This Annual Final Report covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. It is one of the most efficient and cost-effective Full-Service DOD Information Analysis Centers. During this 12-month reporting period, TEPIAC has screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 documents while completely overhauling the system, compiled 2,675 sets of property data, responded to 562 inquiries, published or completed 5 volumes of data books with a total of 1,833 pages, 2 technical reports with a total of 396 pages, and 10 volumes of research literature retrieval guides with a total of 3,097 pages, and distributed 66,000 copies in 6 issues of the "Thermophysics and Electronics Newsletter."</p>	<p>AD</p> <p>UNCLASSIFIED UNLIMITED DISTRIBUTION</p> <p>Key Words Thermophysical properties Electronic properties Electrical properties Magnetic properties Optical properties Information Analysis Center Data compilation, evaluation, analysis, and synthesis</p>
<p>Army Materials and Mechanics Research Center Watertown, Massachusetts 02172 THERMOPHYSICAL AND ELECTRONIC PROPERTIES INFORMATION ANALYSIS CENTER (TEPIAC) - A Continuing Systematic Program on Data Tables of Thermophysical and Electronic Properties of Materials C. Y. Ho, Center for Information and Numerical Data Analysis and Synthesis, Purdue University, West Lafayette, Indiana 47906</p> <p>Technical Report AM98C TR 80-15, March 1980, 111 pp-illus-tables, Contract DLA900-79-C-1007 Annual Final Report, 1 January to 31 December 1979</p> <p>This Annual Final Report covers the activities and accomplishments of TEPIAC in the period 1 January to 31 December 1979. TEPIAC's activities reported include literature search, acquisition, and input of source information; document review and codification; material classification; information organization; operation of a computerized bibliographic information storage and retrieval system; data extraction and compilation; data evaluation, correlation, analysis, synthesis, and generation of recommended values; preparation and publication of handbooks, data books, properties literature retrieval guides, state-of-the-art reports, critical reviews, and technology assessments; development of a computerized numerical data storage and retrieval system; technical and bibliographic inquiry services; and current awareness and promotion efforts. TEPIAC covers 14 thermophysical properties and 22 electronic, electrical, magnetic, and optical properties of nearly all materials at all temperatures and pressures and in all environments. It is one of the most efficient and cost-effective Full-Service DOD Information Analysis Centers. During this 12-month reporting period, TEPIAC has screened 750,000 abstracts, scrutinized 46,000 potentially good entries, identified 11,400 pertinent references, acquired 17,634 research documents, reviewed, coded, and catalogued 1,837 documents while completely overhauling the system, compiled 2,675 sets of property data, responded to 562 inquiries, published or completed 5 volumes of data books with a total of 1,833 pages, 2 technical reports with a total of 396 pages, and 10 volumes of research literature retrieval guides with a total of 3,097 pages, and distributed 66,000 copies in 6 issues of the "Thermophysics and Electronics Newsletter."</p>	<p>AD</p> <p>UNCLASSIFIED UNLIMITED DISTRIBUTION</p> <p>Key Words Thermophysical properties Electronic properties Electrical properties Magnetic properties Optical properties Information Analysis Center Data compilation, evaluation, analysis, and synthesis</p>